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DEPARTMENT OF DEFENSE

UNMANNED AERIAL VEHICLES (UAV)

MASTER PLAN

1992

15 APRIL 1992

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I INTRODUCTION

Unmanned Aerial Vehicles (UAVs)* can make significant contributions to the war-fighting capability of operational forces. They greatly improve the quality and timeliness of battlefield information while reducing the risk of capture or loss of troops, thus allowing more rapid and better informed decision making by battlefield commanders. They are cost effective and versatile systems. While reconnaissance, surveillance, and target acquisition (RSTA)** are the premier missions of UAVs, they can also provide substantial capabilities in electronic warfare (EW), electronic support measures (ESM), command and control and special operations mission areas. UAVs are a particularly valuable adjunct to the Services' aviation communities. They can readily perform a multitude of inherently hazardous missions: those in contaminated environments, those with extremely long flight times, and those with unacceptable political risks for manned aircraft. Alloting these dirty, dull and dangerous missions to UAVs increases the survivability of manned aircraft and frees pilots to do missions that require the flexibility of the manned system.

Recognizing the need for common and interoperable systems, Congress in 1988 directed the Department of Defense (DoD) to consolidate the management of DoD nonlethal UAV programs and to prepare an annual UAV Master Plan. DoD responded by forming a UAV Executive Committee (EXCOM), designating the United States Navy (USN) as Executive Service, forming a UAV Joint Project Office (UAV JPO) and submitting the first UAV Master Plan to Congress. This is the fourth update of the UAV Master Plan. It provides requirements, program plans, management and acquisition strategies for nonlethal UAVs. Lethal UAV programs are addressed in the DoD Standoff Weapons Master Plan.

Further refining the program in 1991, DoD dissolved the UAV EXCOM and replaced it with the Defense Acquisition Board (DAB). The first UAV DAB review was held on 10 December 1991. The Acquisition Decision Memorandum (ADM) resulting from the DAB approved the designation of the Close Range (CR), Short Range (SR), and Medium Range (MR) UAVs as individual Acquisition Category (ACAT) 1D programs. A similar decision on the Vertical Takeoff and Landing (VTOL) UAV, formerly called the Maritime UAV, was withheld pending completion of technology demonstrations and identification of program funding.

The UAV JPO's mission is to expeditiously field quality UAV systems which provide a significant tactical advantage to operational commanders. It is the DoD "center of excellence" for UAVs and provides advice and guidance to other federal agencies interested in employing UAVs. The UAV JPO is guided by the following management principles:

- Continuously improve the process to develop, procure, and support UAVs.

- Develop an affordable family of UAV systems that are interoperable.

* This Master Plan only addresses non-lethal UAVs. See Appendix A for definitions of UAV related terminology.
** Acronyms are only defined when first used in text. Appendix B defines acronyms used more than once.

- Proactively foster the use of non-developmental items and commonality in order to achieve lowest operational cost.

- Continuously address and support the expectations of all UAV customers; consider the users as partners with the UAV JPO.

The UAV Master Plan is a reflection of these guiding principles. A summary of the significant 1991 accomplishments in the UAV program and in the program being executed in 1992 are provided below.

THE 1991 ACCOMPLISHMENTS AND ACHIEVEMENTS FOR THE UAV PROGRAM INCLUDE:

PIONEER UAV

- Supported UAV activities and involvement in Operation Desert Storm. UAVs deployed by the United States Army (USA), USN and United States Marine Corps (USMC).

SR UAV

- Initiated Technical Evaluation Test (TET) of the SR UAV.

- Procured SR UAV hardware for the Joint Technology Center/Systems Integration Laboratory (JTC/SIL).

- Completed propulsion testing of competing SR air vehicles.

- Obtained approval of the SR UAV Test and Evaluation Master Plan (TEMP) by Office of the Secretary of Defense (OSD).

CR UAV

- Implemented a risk reduction program for the CR system for a 200 pound (lb.) class air vehicle and lightweight forward looking infrared (FLIR) payload.

VTOL (Formerly MARITIME) UAV

- Prepared a VTOL UAV Development Options Paper (DOP) in response to Office of the Chief of Naval Operations (OPNAV) Maritime Tentative Operational Requirement (TOR).

- Conducted operational demonstration of the CL-227 aboard a USN frigate with participation of the Navies of Canada, Germany, the Netherlands, France and the United Kingdom.

- Awarded competitive contracts to Bell Helicopter Textron and Science Applications International Corporation (SAIC) for studies of a Tilt Wing/Rotor UAV.

MR UAV

- Obtained approval of the redefined MR UAV program by the Assistant Secretary

of the Navy (Research, Development & Acquisition) (ASN[RD&A]).

- Signed multi-Service MR interfacing program memorandums of agreement (MOAs).

- Conducted successful captive carry of the new composite MR UAV vehicle.

DRUG ENFORCEMENT

- Continued support of UAV counternarcotic activity with the Drug Enforcement Administration (DEA).

VERY LOW COST (VLC) UAV

- Awarded a competitive contract to BAI Aerosystems, Inc. for 110 EXDRONES for operational demonstration.

INTEROPERABILITY & COMMONALITY (I&C)

- Prepared the capstone specification to establish standard UAV systems architecture.

- Prepared design guidance for UAV air vehicles.

- Documented and verified the Joint Integration Interfaces (JIIs) for UAV air vehicles and avionics.

- Continued development of modular avionics and millimeter wave radar autoland technology demonstrations.

MANAGEMENT

- Established the UAV Joint International Programs Directorate effective 1 October 1991.

- Established and chartered the UAV Joint Logistics Center of Excellence (JL-COE).

- Participated in the Joint Requirements Oversight Council (JROC) Special Study Group (SSG) Working Group for UAV payloads.

THE 1992 MAJOR OBJECTIVES FOR THE UAV PROGRAM INCLUDE:

SR UAV

- Complete TET and conduct Limited User Test (LUT) I for SR UAV.

- Competitively select prime contractor for SR UAV and exercise contract option for low rate production (LRP).

- Complete DAB LRP decision for SR UAV program by September 1992.

CR UAV

- Demonstrate 200 lb. class air vehicle and lightweight FLIR payload sensors for CR UAV.
- Complete Milestone (MS) I for CR UAV program by September/October 1992.

VTOL UAV (Not presently resourced)

- Prepare the VTOL UAV program for MS II in accordance with Department of Defense 5000 series.
- Formalize and initiate negotiations for North Atlantic Treaty Organization (NATO) cooperative VTOL UAV program.
- Pending availability of funding, award the contract option(s) for the Tilt Wing/Rotor risk reduction demonstration .

MR UAV

- Complete MR UAV contractor flight test (CFT-1) and ground launch of the composite vehicle.
- Complete MR UAV preliminary design review (PDR).
- Obtain MR UAV TEMP approval.

INTEROPERABILITY & COMMONALITY (I&C)

- Finalize, approve and publish the UAV family capstone specification.
- Prepare development specifications for heavy fuel engines, modular avionics and automatic recovery systems for UAV family application.
- Complete JII documents which ensure operational interoperability of UAV family systems.

PIONEER UAV

- Purchase Pioneer spares and equipment to replace those expended in Southwest Asia.

— UAV 1992 MASTER PLAN

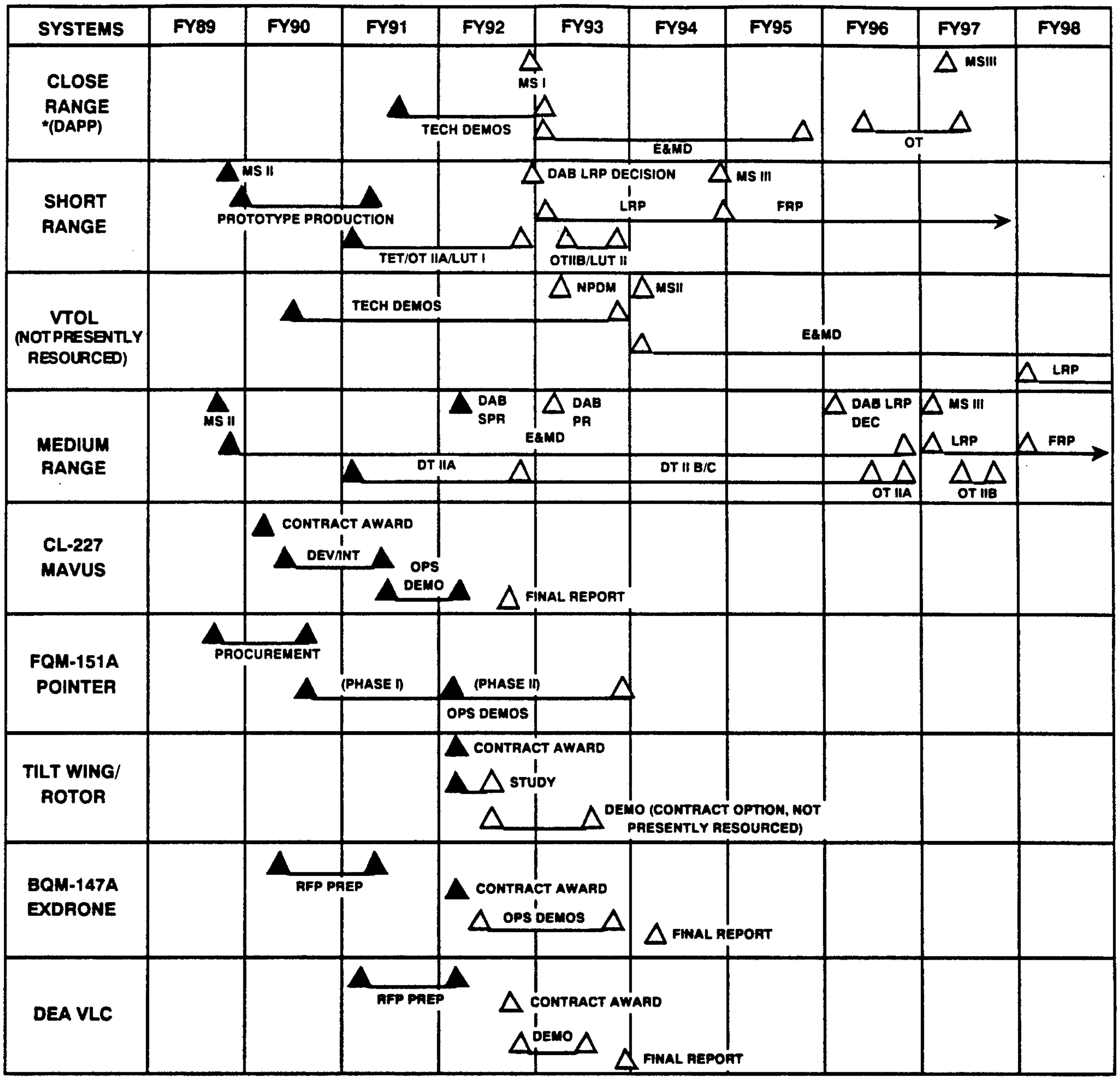


Figure 1 UAV Master Schedule

* Defense Acquisition Pilot Program

II MANAGEMENT

In response to congressional direction in FY88 to consolidate the management of DoD nonlethal UAV programs, the Under Secretary of Defense (Acquisition) (USD[A]) established the UAV JPO. An EXCOM was established with overall responsibility for DoD UAV programs at the OSD level. In 1991 the EXCOM was disestablished and DoD UAV programs were brought under DAB procedures and management (See Figure 2).

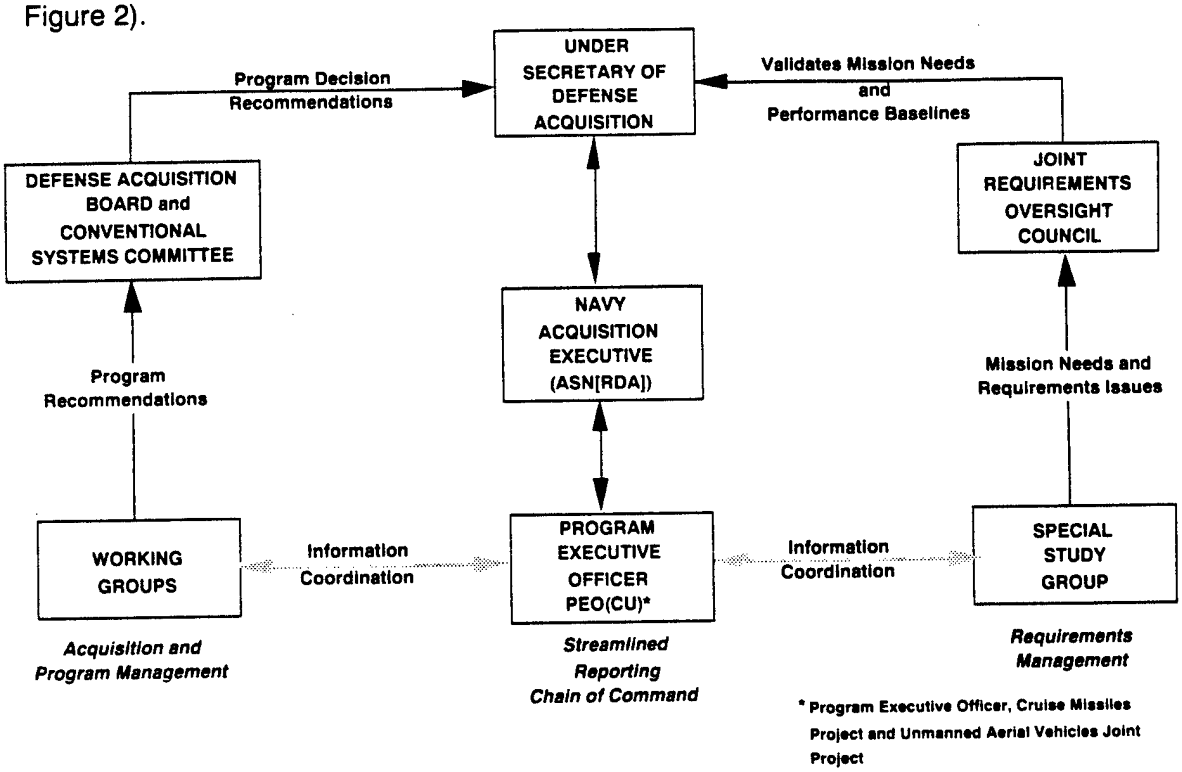


Figure 2 UAV Management Organization

The USN is the Executive Service for the UAV JPO, with responsibility and accountability for designing, developing, procuring and transitioning UAV systems to the Services. The systems must meet the requirements validated by the JROC commensurate with available funding. The DAB and Conventional Systems Committee (CSC) maintain oversight, provide program direction and approve milestones.

The UAV JROC SSG is responsible for consolidating and reconciling requirements before presenting them to the JROC for approval. SSG working groups support the SSG. The UAV JPO confers with the Working Groups and the SSG to resolve requirements-related issues.

The UAV Working Group conducts activities required by the DAB and CSC. Chaired by OSD (C^3I), the Working Group includes representatives of the DAB/CSC, plus the National Security Agency (NSA), Defense Advanced Research Projects Agency (DARPA), UAV JPO and other designated elements of OSD and Service staffs.

In 1988 the UAV JPO was established as the central management authority for all DoD non-lethal UAV acquisition efforts. In 1990, the USN transitioned to the Program

Executive Officer (PEO) structure. The UAV JPO receives its program guidance via the chain of command depicted in Figure 2. Composed of technical, business and program management personnel, the organization is responsible for planning and executing UAV JPO development and acquisition programs. The UAV JPO ensures that present and planned developments satisfy requirements validated by the JROC. Additionally, the UAV JPO guides and coordinates appropriate UAV advanced technology that supports new/emerging requirements, coordinates international efforts of participating Services and promotes UAV cooperation. The UAV JPO is also charged to maintain leadership in UAV system acquisition and to advocate UAVs as a significant warfighting advantage to operational commanders. Its objective is to field an affordable family of interoperable systems that optimizes commonality, is accepted by the Services and is integrated in the DoD and Allied battleforce architectures.

III REQUIREMENTS

Mission Need Statements (MNSs) for four categories of UAV capabilities (Close, Short, Medium and Endurance) have been validated by the Chairman of the JROC. Figure 3 provides a summary of UAV MNS required capabilities. Operational Requirements Documents (ORDs) that expand upon and refine MNS baselines are in staffing for the CR, SR, VTOL (SR Block I), and MR UAV categories.

	CLOSE	SHORT	MEDIUM	ENDURANCE
OPERATIONAL NEEDS	RS, TA, TS, EW, MET, NBC	RS, TA, TS, MET, NBC, C2, EW	PRE-AND POST-STRIKE RECONNAISSANCE TA	RS, TA, C2, MET, NBC, SIGINT, EW, SPECIAL OPS
LAUNCH AND RECOVERY	LAND/SHIPBOARD	LAND/SHIPBOARD	AIR/LAND	NOT SPECIFIED
RADIUS OF ACTION	NONE STATED	150 KM BEYOND FORWARD LINE OF OWN TROOPS (FLOT)	650 KM	CLASSIFIED
SPEED	NOT SPECIFIED	DASH >110 KNOTS CRUISE < 90 KNOTS	550 KNOTS < 20,000FT, .9 MACH > 20,000 FT	NOT SPECIFIED
ENDURANCE	24 HRS CONTINUOUS COVERAGE	8 TO 12 HRS	2 HRS	24 HRS ON STATION
INFORMATION TIMELINESS	NEAR-REAL-TIME	NEAR-REAL-TIME	NEAR-REAL-TIME/ RECORDED	NEAR-REAL-TIME
SENSOR TYPE	DAY/NIGHT IMAGING*, EW, NBC	DAY/NIGHT IMAGING*, DATA RELAY, COMM RELAY, RADAR, SIGINT, MET, MASINT, TD, EW	DAY/NIGHT IMAGING*, SIGINT, MET, EW	SIGINT, MET, COMM RELAY, DATA RELAY, NBC, IMAGING, MASINT, EW
AIR VEHICLE CONTROL	NONE STATED	PRE-PROGRAMMED/ REMOTE	PRE-PROGRAMMED	PRE-PROGRAMMED/ REMOTE
GROUND STATION	VEHICLE & SHIP	VEHICLE & SHIP	JSIPS (PROCESSING)	VEHICLE & SHIP
DATA LINK	WORLD WIDE PEACE TIME USAGE, ANTI-JAM CAPABILITY	WORLD WIDE PEACE TIME USAGE, ANTI-JAM CAPABILITY	JSIPS INTEROPERABLE WORLD WIDE PEACE TIME USAGE, ANTI-JAM CAPABILITY	WORLD WIDE PEACE TIME USAGE, ANTI-JAM CAPABILITY
CREW SIZE	MINIMUM	MINIMUM	MINIMUM	MINIMUM
SERVICE NEED/ REQUIREMENT	USA, USN, USMC	USA, USN, USMC	USN, USAF, USMC	USA, USN, USMC

* Baseline Payload Capability

LEGEND

C2 - COMMAND AND CONTROL
EW - ELECTRONIC WARFARE
JSIPS - JOINT SERVICE IMAGERY PROCESSING SYSTEM
MASINT - MEASUREMENT AND SIGNATURES INTELLIGENCE
MET - METEOROLOGY
NBC - NUCLEAR, BIOLOGICAL and CHEMICAL RECONNAISSANCE
RS - RECONNAISSANCE AND SURVEILLANCE
SIGINT - SIGNALS INTELLIGENCE
TA - TARGET ACQUISITION
TS - TARGET SPOTTING
TD - TARGET DESIGNATOR

Figure 3 MNS Summary

CATEGORIES OF CAPABILITIES

The categories of required capabilities, generally described by desired UAV system characteristics in the UAV MNS, are depicted graphically in Figure 4 on the following page. CR capabilities address the needs of lower level tactical units such as USA

divisions and brigades/battalions and USMC battalions/companies for a capability to investigate activities within their local area of interest, (approximately 30 kilometers [km]). Systems must be easy to launch, operate and recover; require minimum manpower, training and logistics; and be relatively inexpensive.

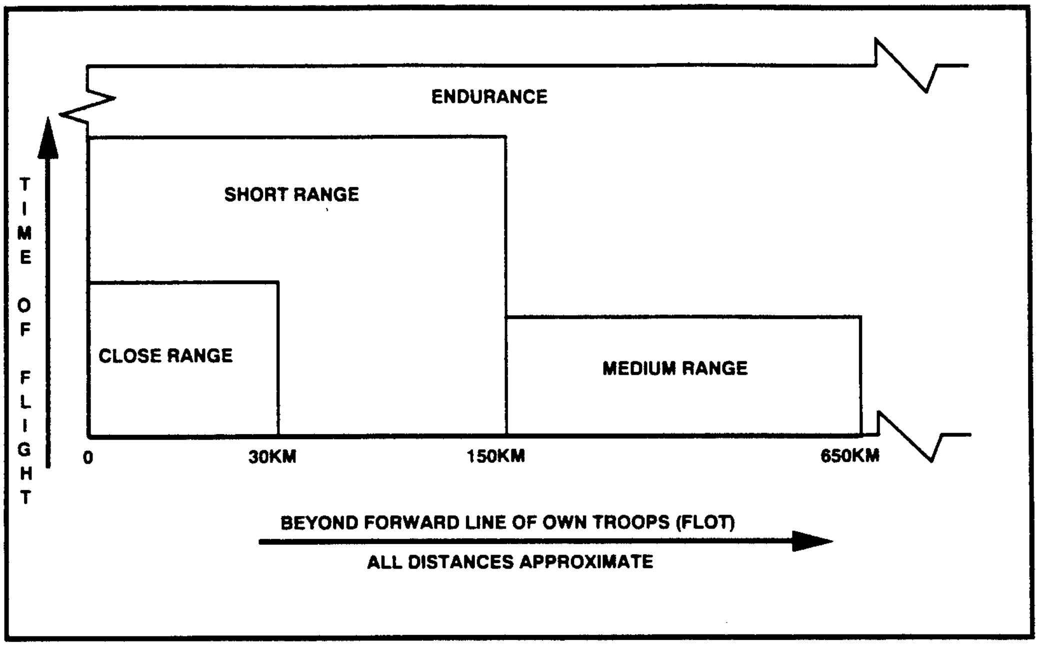


Figure 4 Categories of Capabilities

SR capabilities support USA division through echelons above corps level and USMC Air-Ground Task Force (MAGTF) level. Enemy activities out to a range of 150 km or more beyond the forward line of own troops (FLOT) or datum point (in USN operations) are a focus of SR activities. These UAV systems are more robust and sophisticated, can carry a wider variety of payloads, and can perform more kinds of missions than CR systems.

MR capabilities address the need to provide pre- and post-strike reconnaissance of heavily defended targets and augment manned reconnaissance platforms by providing high quality, near-real-time imagery. They differ from other UAV capabilities in that the vehicle is designed to fly at high subsonic speeds and spend relatively small amounts of time over target areas of interest.

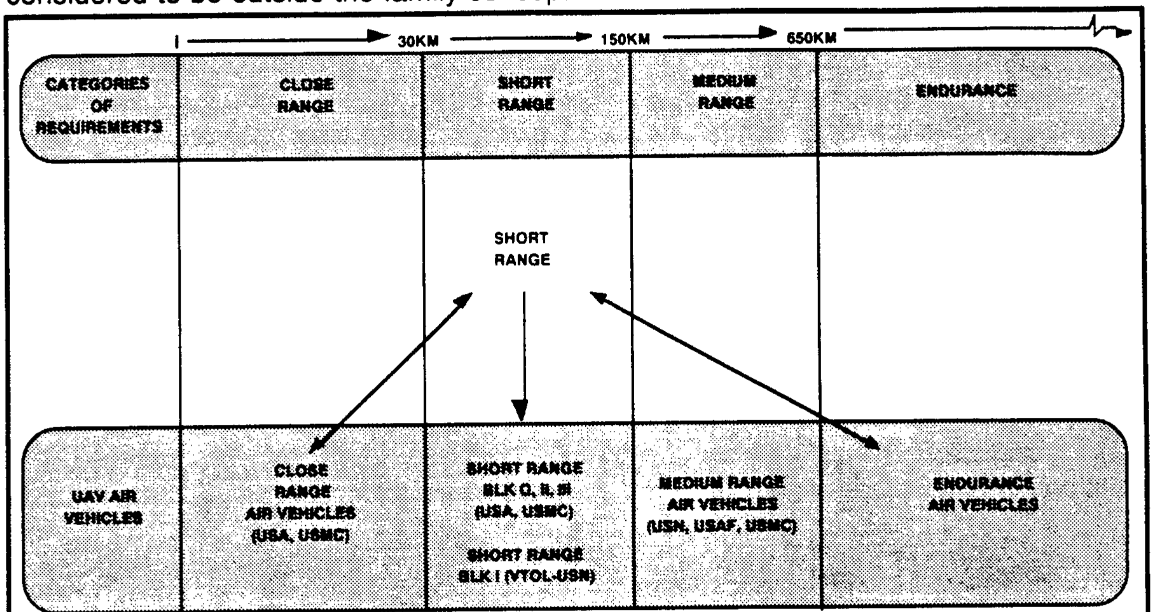
Endurance capabilities respond to a wide variety of mission needs and address the capability to carry many types of payloads. Endurance systems are characterized by times of flight measured in days and very great ranges and altitudes of flight.

FAMILY CONCEPT

Establishment of a family of UAV systems that are interoperable and common is the core strategy of the UAV JPO. As Figure 5 illustrates on the following page, the SR system is the centerpiece of the strategy. It provides a baseline system capability that

maximizes I&C with CR and future VTOL and Endurance UAV systems.

Due to its unique mission which requires higher resolution imagery and its development start pre-dating the formation of the UAV JPO, the MR system I&C is driven by the Joint Service Imagery Processing System (JSIPS) and the Advanced Tactical Air Reconnaissance System (ATARS) interface requirements, and is therefore considered to be outside the family concept.



SHORT RANGE UAV IS THE CENTERPIECE

Figure 5 Categories of Required UAV Capabilities

PLANNED PROCUREMENT

Figure 6 below provides planned procurement for each UAV system. The reader is cautioned that Figure 6 is only an estimate subject to change, based on budgetary constraints and other factors.

	CR	SR	VTOL	MR
Air Vehicles	1260	384	140	550
Payloads	1878	768	208	542
Systems*	176	48	—	—

*A system may include air vehicle(s), more than one kind of payload, mission planning and control station (MPCS) equipment, launch and recovery equipment and ground support equipment.

Figure 6 Planned Procurement

IV ACQUISITION STRATEGY

UAV acquisition strategy is focused on fielding systems rapidly to meet operational requirements with common and interoperable systems. It includes:

- Harmonizing operational requirements among the Services and Unified and Specified Combatant Commands.

- Procuring off-the-shelf technologies and commercially available components for initial systems, thereby reducing cost, risk and duration of development.

- Developing specifications for systems after the Services have acquired hands-on operational experience. Operational experience is essential for reducing costs by providing users the basis for establishing specific performance specifications.

- Conducting and monitoring advanced research and development that enhances the systems' future capabilities. Advanced technologies are incorporated through block upgrades.

- Maintaining all equipment interfaces, interface control documents and specifications to ensure effective block upgrades and interchangeability of systems and subsystems.

- Ensuring interoperability among all systems and subsystems with the command, control, communications and intelligence (C^3I) systems of the Services and the Unified and Specified Commands.

- Employing a competitive and evolutionary acquisition process to incorporate block upgrades to air vehicles, payloads, data links, MPCSs, launch and recovery and logistic support sub-systems. Figure 7 below provides an estimated breakout of representative UAV subsystem acquisition cost.

- Encouraging an allied acquisition strategy that will enhance system I&C as a force multiplier.

The above strategy is in general applicable to all the UAV categories; however, as explained in Section III, the parts of the strategy related to I&C are not applicable to MR.

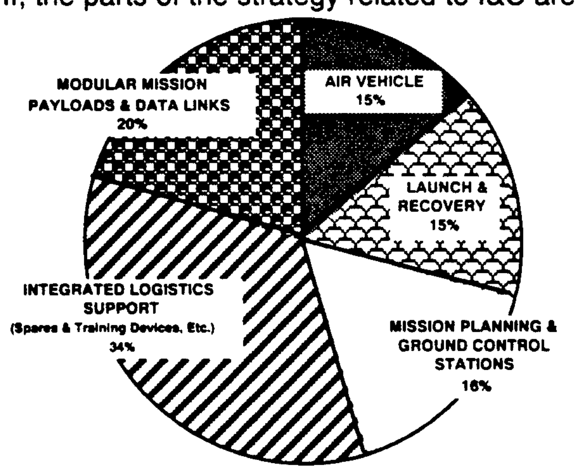


Figure 7 Program Acquisition Cost Breakout (Estimated)

V INTEROPERABILITY AND COMMONALITY (I&C)

The modern battleforce environment, within which UAV systems must operate over the next decade, is complex and will most likely involve combined forces from various Service elements. The UAV JPO strategy recognizes that UAV system I&C is basic to the successful acquisition of a family of affordable and operationally effective UAV systems. Concepts which shape the UAV JPO program are:

- UAV systems must be designed to fit into Service C^3I architectures and with other UAV systems to be used effectively in multi-Service and Unified and Specified Command operations.

- UAV systems have many common functions and should share as much common equipment and associated software as is practical to reduce life cycle cost and simplify logistics support functions.

- UAV systems must allow for growth in performance and readily accommodate new component technologies to have long term utility in the field.

These concepts require a disciplined system engineering approach to the acquisition and fielding of a family of affordable and operationally effective UAV systems. The elements of this approach are described below and illustrated in Figure 8.

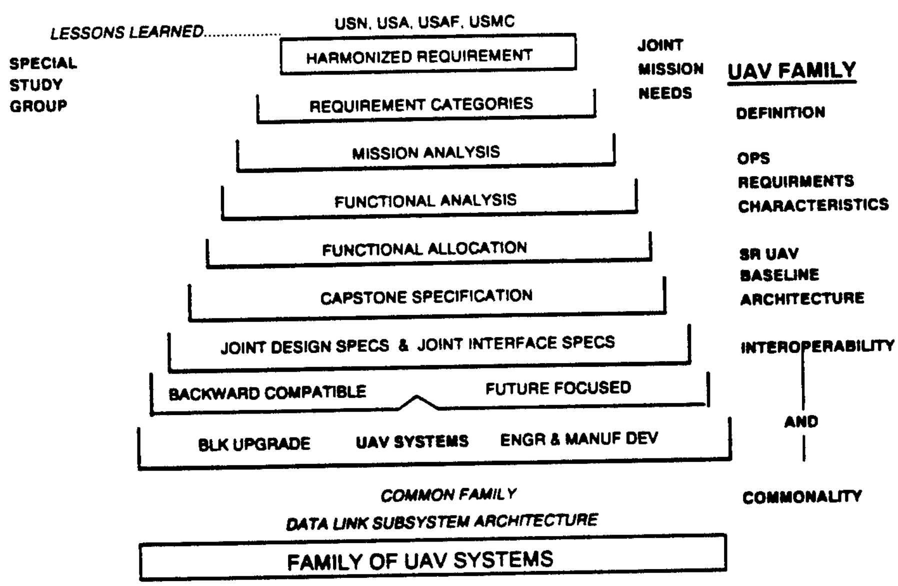


Figure 8 Requirements Based Approach To UAV Family Design

A. ARCHITECTURE CONTROL

1. Establish a common UAV system design architecture and develop a "capstone specification" using the winning SR UAV system design as a developmental baseline.

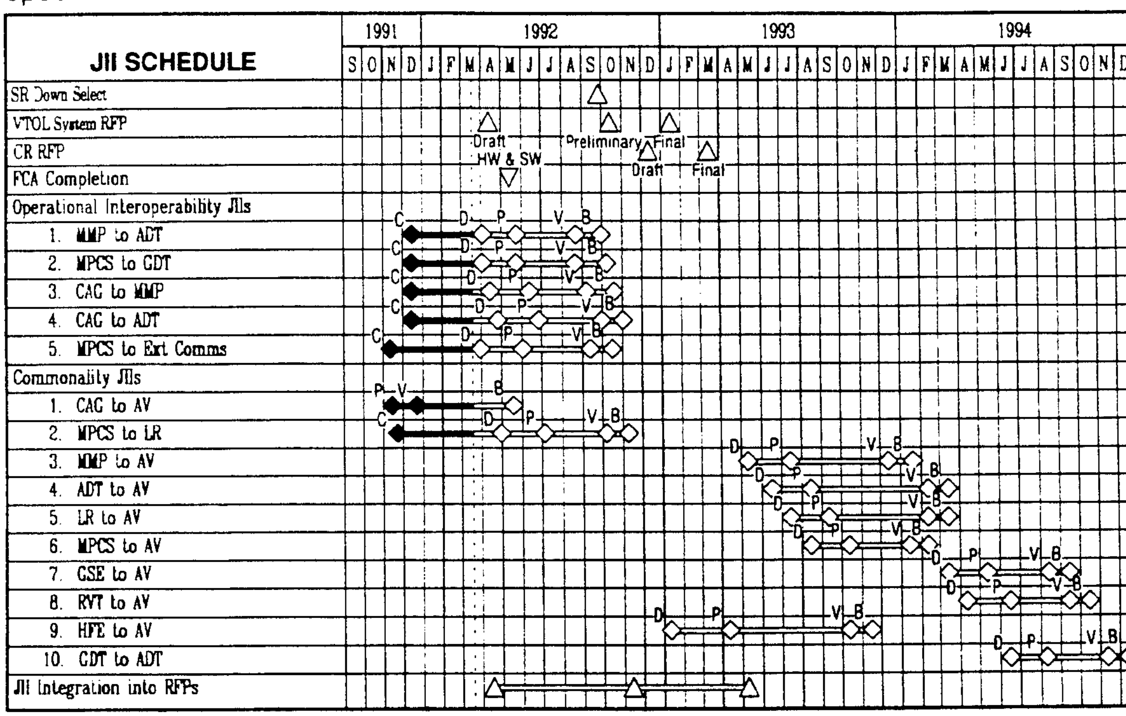
2. Standardize and control a requirements-based set of subsystem operating interfaces related to the capstone specification. Develop appropriate design guidelines.

3. Develop an interoperable data link subsystem architecture for the UAV family to ensure communications connectivity.

A Joint UAV Steering Committee (JUSC), chaired by the UAV JPO Director, has been established to review and control joint architecture and interoperability initiatives.

B. INTEROPERABILITY

To achieve I&C, UAV systems must be integrated in a manner which provides functional interfaces between systems, subsystems and components of the UAV family. The UAV JPO concept of a UAV family architecture accommodates off-the-shelf equipment and future insertion of advanced technologies. A system engineering and integration agent (SEIA) maintains all system and subsystem interfaces, interface control documents, and specifications to ensure effectiveness, block upgrades and interchangeability of systems and subsystems. JIIs, shown in Figure 9, are being developed.



LEGEND:

ADT	= Air Data Terminal	FCA	= Functional Configuration Audit	MPCS	= Mission Planning and Control Station
AV	= Air Vehicle	GDT	= Ground Data Terminal	MMP	= Modular Mission Payload
B	= Baseline JII	GSE	= Ground Support Equipment	P	= Preliminary
CAG	= Common Avionics Group	HFE	= Heavy Fuel Engine	RVT	= Remote Video Terminal
C	= Concept JII	LR	= Launch and Recovery	V	= Verification Complete
D	= Draft JII				

Figure 9 JII Verification Schedule

JIIs provide the architecture and interface framework required to ensure I&C. A JII consists of appropriate UAV Short Range Block 0 interface control document (ICD) parameters plus upgrades based on new or state-of-the-art technologies. Each JII, as its specification is developed, is verified for functional integrity and performance at the UAV JPO Joint Development Facility (JDF). JIIs will also be validated for functional performance with UAV hardware at the JTC/SIL. JDF and the JTC/SIL capabilities ensure successful implementation of JIIs and achievement of I&C objectives for the UAV family.

Maximum design flexibility will be incorporated in each JII in order to accommodate the controlling parameters of each component shown in Figure 9. To maximize I&C, the

components will be designed to meet the family interface design requirements (i.e.,electrical, software message formats) of one or a combination of JIIs cited in Figure 9. For each technology component, the associated JIIs will be verified and validated before and after development testing, respectively.

The JDF, located at Tysons Corner, VA, is chartered by the UAV JPO to verify JIIs used in UAV systems. The JDF provides a "closed loop" simulation of the UAV system based on concepts of operation from each UAV program. The simulations are real time man-in-the-loop tests representative of the mission requirements of the UAV design under test. Each UAV subsystem/component is normally represented by a simulation and/or hardware interface module. Component simulations may also be replaced by an actual UAV component, such as the workstation shown in Figure 10, to verify component functionality.

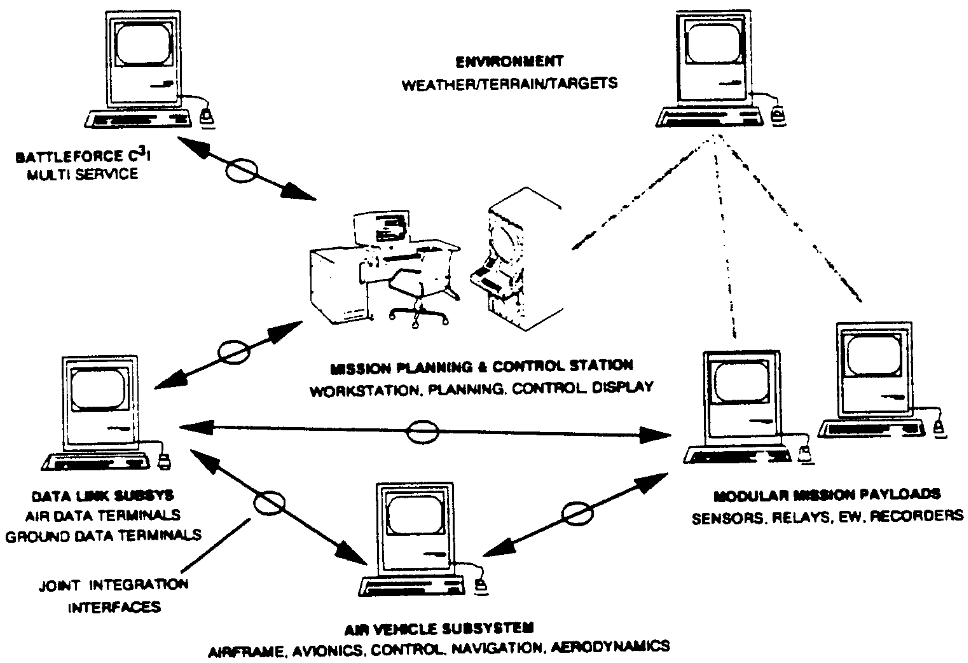


Figure 10 Joint Development Facility (JDF)

The JTC/SIL is located at Redstone Arsenal, AL where it can utilize to the maximum facilities that are presently in existence at the USA Missile Command's Research, Development and Engineering Center. The SR UAV system is the first to be installed in the JTC/SIL, and will be the baseline for future installations. It is planned that each new UAV system will have its unique test bed interfaced with the common UAV system components.

The JTC/SIL is a laboratory that serves as the joint test bed or bureau of standards for the family of UAVs. It provides facilities for complete simulation or hardware-in-the-loop evaluation of UAV systems and integrated UAV hardware and software elements. I&C is validated and hardware and software baseline configurations of fielded systems are established. The JTC/SIL also performs independent verification and validation of resident UAV system software and hardware during the development phase of programs and provides post development software and hardware support to the UAV program managers. The facility also provides communications gateways to various other system developers, which permits verification and validation of battle-field/battleforce C^3I interfaces. The JTC/SIL also provides a capability for industry to

demonstrate the application of new hardware and software in existing UAV systems. Plans are being formulated to integrate the functions of the JDF with the JTC/SIL not later than FY95.

C. TECHNOLOGY

The UAV JPO approach includes integration of off-the-shelf equipment to provide timely UAV capabilities to tactical commanders and technology initiatives to ensure availability of advanced capabilities for new systems and upgrades to fielded systems.

1. Collaborate with DARPA and Service laboratories to identify and coordinate UAV related technology development efforts.

A Joint Technology Steering Committee (JTSC), chaired by the UAV JPO Systems Engineering and Analysis Directorate and with DARPA, NSA and Service laboratory membership, has been formed. The function of the JTSC is to identify, monitor, and coordinate UAV related technology development efforts and to advise the JUSC on UAV technology matters. A MOU between DARPA and the UAV JPO dealing with UAV related technology is being established. For UAV systems the JTSC provides a coordinated input to the UAV JPO and DARPA Advanced Technology Plan

2. Collaborate with government and industry to identify opportunities to evaluate component technology for common application to the family of UAV systems.

MOUs between NSA and the UAV JPO and the USA Program Executive Officer for Intelligence and Electronic Warfare [PEO (IEW)] and the UAV JPO for coordination of signals intelligence (SIGINT) ESM technology applications are being established. The UAV JPO utilizes the "Association for Unmanned Vehicle Systems" and briefings to professional societies as forums for government and industry information exchange.

3. Conduct laboratory experimentation to determine maturity and feasibility associated with integration of developing UAV component technologies.

4. Demonstrate and evaluate matured UAV component technologies to determine suitability, effectiveness, and risk associated with application to UAV family requirements.

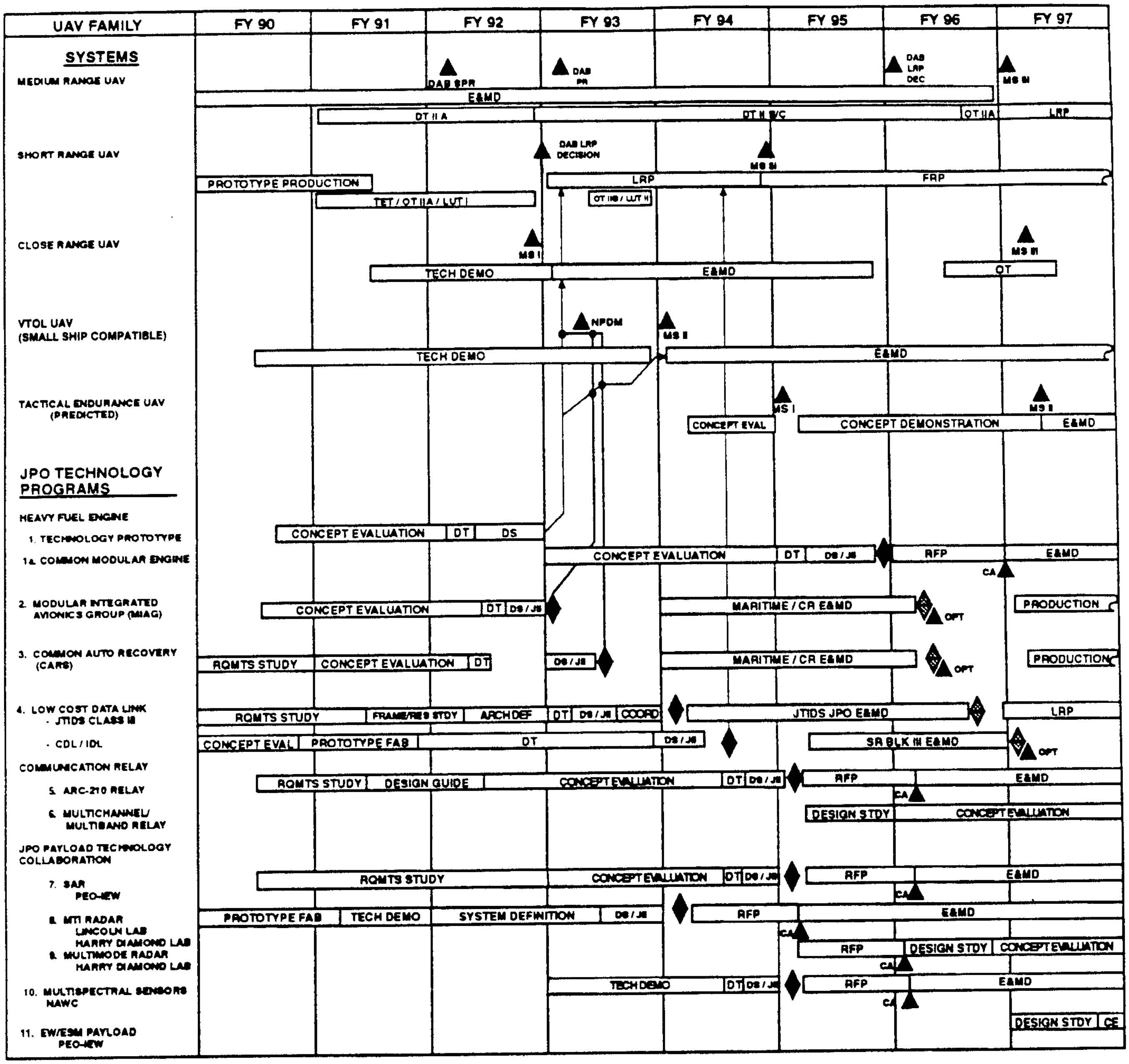
5. Transition component technology to UAV systems in the form of low risk specifications derived from UAV JPO technology performance evaluations.

D. COMMONALITY

1. Philosophy

- Consider use of existing UAV system components and software modules when formulating development options for new UAV capabilities. The CR and VTOL UAV developments will maximize use of SR UAV components and associated software.

- Develop a Commonality Plan which defines the UAV JPO approach for phased implementation of commonality within the UAV family. Particular focus is on developing state-of-the-art components which support common UAV system functions (e.g., avionics, engines, etc.) and on payload components (e.g. sensors, relays, ESM, etc.). Figure 11 describes proposed milestones and critical decision/program transition



- ◆ JUSC COMMONALITY DECISION (JPO)
- ◈ JUSC COMMON COMPONENT PRODUCTION DECISION (JPO)
- ▲ MAJOR SYSTEM MILESTONE
- DS DEVELOPMENT SPECIFICATION
- JII JOINT INTEGRATION INTERFACE

Figure 11 Commonality Implementation Plan

points for development and implementation of common UAV components over the next decade based on the Program Objective Memorandum (POM) 94 input.

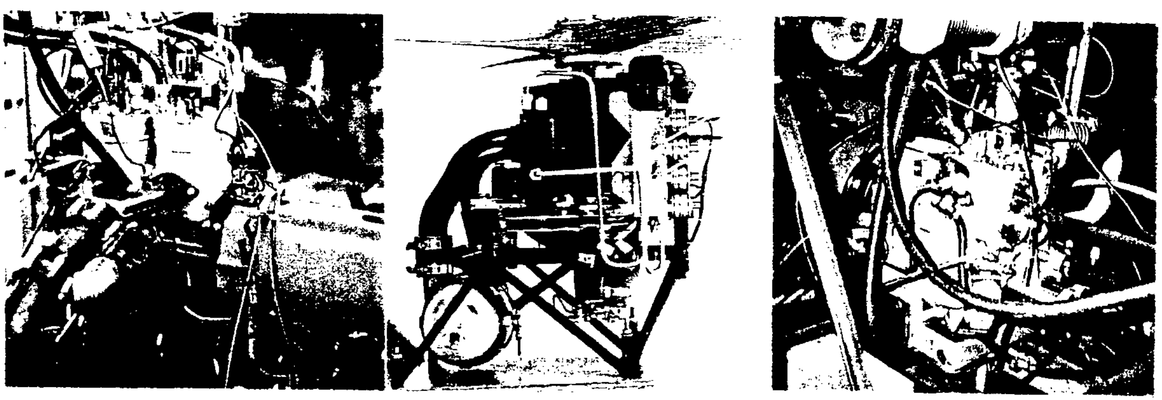
2. Project Status

The UAV JPO Systems Engineering and Analysis Directorate evaluates existing UAV components and off-the-shelf and commercially available equipment which have potential for common application to UAV family needs. Successful evaluation may result in identification of component hardware and/or software as a commonality candidate to the JUSC.

The JUSC reviews identified commonality opportunities and authorizes UAV JPO commonality initiatives. Several UAV JPO component technology evaluation efforts are underway to assess potential for UAV family application and to identify commonality opportunities.

a. Evaluation of a lightweight, highly efficient, heavy fuel (JP-5, JP-8, or diesel) engine technology for common application to the UAV family.

The Naval Air Warfare Center Aircraft Division, Trenton, NJ (NAVAIRWARCENACDIV TRN) has contracted for demonstration of three unique heavy fuel engine designs with Southwest Research, Inc., San Antonio, TX; AAI, Hunt Valley, MD; and DGI, Farmingdale, NY (shown in Figure 12). Contractor testing is completed. NAVAIRWARCENAC-DIV TRN will complete independent government tests in 1992. A performance specification reflecting the demonstrated technology will be used to reduce risk associated with the planned SR UAV Block II engine upgrade. If funding allows, a follow-on program to specify a modular core heavy fuel engine as a common component candidate for the UAV family will be conducted.



Southwest Research, Inc.
Engine in Test Cell

AAI
Rotary Heavy
Fuel Engine

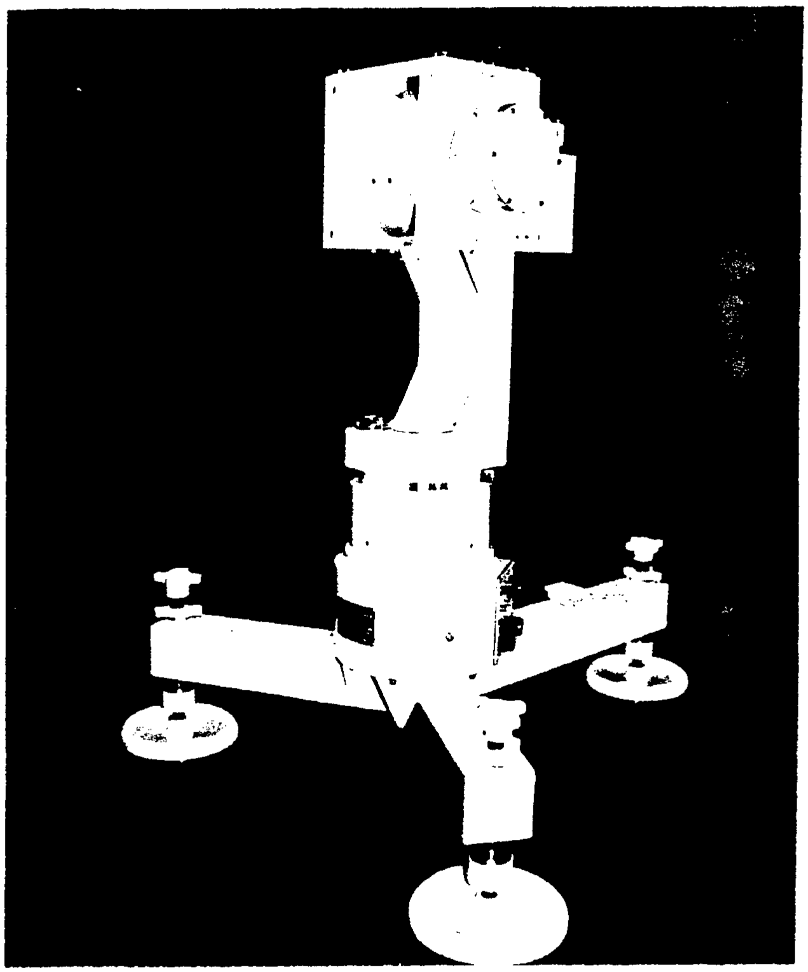
DGI
Heavy Fuel Engine

Figure 12 Unique Heavy Fuel Engine Designs for UAVs

b. Evaluation of technology suitable for an all-weather capable system to automatically recover various classes of UAVs.

The UAV JPO has contracted with the Sierra Nevada Corp., Reno, NV for demonstration of lightweight, portable, millimeter wave radar tracking and vehicle control

interface components. These components have a potential for common application to UAV family recovery needs. Fabrication and factory testing of prototype equipment are complete (shown in Figure 13). Land based testing, using a VTOL UAV system (Canadair CL-227) will be completed in mid-1992. A specification based on demonstrated performance will be used by SR UAV, CR UAV, and VTOL UAV program managers to reduce recovery system development risk. If funding allows, a follow-on effort to demonstrate recovery system performance on a moving ship platform is planned as part of a VTOL UAV risk reduction effort. Successful demonstrations will result in UAV JPO consideration of components based on this technology as candidates for UAV family commonality.



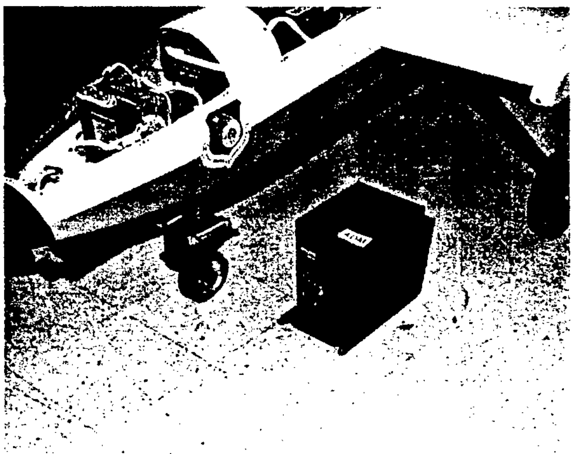
Tracking System

Figure 13 Millimeter Wave Radar All-Weather Capability System

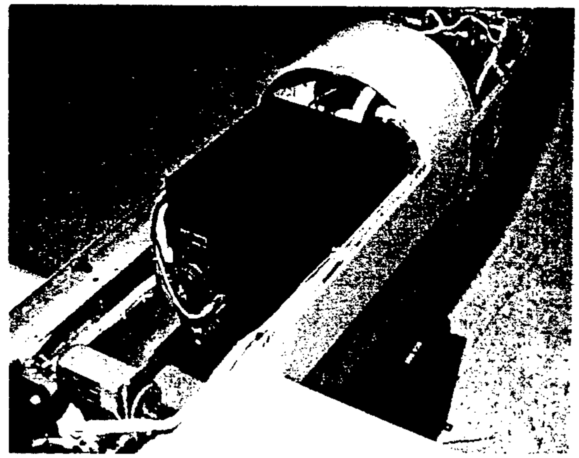
c. Evaluation of avionics packaging technology to provide a compact, lightweight, integrated avionics unit to accomplish common UAV avionics flight management and navigation functions.

The United States Air Force (USAF) Wright Laboratory, Dayton, OH has contracted with Lear Astronics, Santa Monica, CA, to fabricate and demonstrate a modular integrated avionics group (MIAG), [formerly called the common core avionics group (CCAG)], including flight management, global positioning system (GPS), and a solid state inertial measurement unit (IMU). Development hardware containing the flight management

function (shown in Figure 14) has been successfully exercised in an unmanned vehicle testbed. If funding allows, the GPS, and IMU functions will be integrated and tested in 1992. A performance specification reflecting the demonstrated technology will be used by the CR UAV and VTOL UAV program managers to reduce development risk. The UAV JPO is considering a MIAG package as a candidate for commonality within the UAV family.



MIAG Beside an Unmanned Research Vehicle



MIAG Installed in Unmanned Research Vehicle for Flight Testing

Figure 14 Flight Management Development Hardware

d. Evaluate tactical communications relay technology for application as a common UAV family payload.

The Naval Air Warfare Center Aircraft Division, Indianapolis, IN (NAVAIRWARCENACDIV IND) is designing and will fabricate a two channel communications relay prototype based on the ARC-210 jam-resistant tactical radio. Testing of the prototype relay installed in a UAV should be complete by the end of 1993. Successful evaluation will result in a tactical communications relay payload specification for the UAV family. The UAV JPO will consider this as a candidate payload for commonality within the UAV family.

e. Establishment of a payload technology data base to assess state of the art equipment, capabilities and applicability to UAV mission requirements.

The UAV JPO has completed an initial survey of developmental and off the shelf commercial and military sensors, EW, and communications relay equipment. An unclassified version of this data is provided in Appendix D, including a subjective analysis of the potential suitability of each payload type for current or future application to UAV mission requirements. This payload data base will be expanded and maintained as a reference to assist the UAV JPO and the UAV SSG Payload Working Group in determining UAV payload development priorities.

The SSG Payload Working Group was formed this past year to address UAV payload

needs. Baseline payloads for all categories of UAVs include electro-optical (EO), IR and multisensor. For the SR UAV, an additional baseline requirement is a command and control air data relay to pass data from a forward deployed UAV. The Working Group has established the following broad listing of growth payloads (in alphabetical order, not priority order): communications and data relay, communications intelligence (COMINT), communications jammer, electronic countermeasures (ECM), decoy, electronic intelligence (ELINT), laser designator, meteorological, mine detection, NBC, non-communications jammer, and synthetic aperture radar (SAR), including moving target indicator (MTI), inverse SAR (ISAR), mapping mode, and search mode. Review and approval by the JROC of the Working Group's efforts is expected by summer 1992. The Working Group's prioritization of payload development needs of the Services will be addressed in subsequent refinements of the advanced technology roadmap and plans, and the SR Block II and III plans.

E. COMMUNICATIONS INTEROPERABILITY

It is essential that UAV systems interoperate with communication systems. All UAV GCSs should be able to control, and receive and exploit mission data from, different air vehicles, regardless of the system mix.

1. The UAV JPO is evaluating existing data link communications technology for potential application to the establishment of a common, interoperable data link subsystem for the UAV family. This is challenging since such a data link must first be interoperable with the SR baseline, and all subsequent UAV systems including CR, VTOL and Endurance.

2. A key UAV JPO objective is to minimize the number of new data links required as a result of the UAV integration into the Services' force structure. Therefore, the UAV JPO is evaluating existing data links of the Services' C^3I systems for possible co-use as UAV data links. An initial study indicates that scaled down versions of the Joint Tactical Information Distribution System (JTIDS) and/or DOD's Common Data Link (CDL)/Interoperable Data Link (IDL) equipments could have potential for use as low cost UAV data link components. Cooperative UAV JPO/PEO(IEW) evaluation of prototype low cost CDL/IDL hardware and a UAV JPO evaluation of low cost JTIDS at the JDF to assess integrated system functionality are planned in 1992. Assuming the concepts of low cost and lightweight JTIDS and CDL/IDL are proven, the JTIDS and the CDL/IDL could be added to the family baseline architecture during future block upgrade. Development of a common UAV family data link subsystem architecture incorporating the SR baseline link, JTIDS, and CDL/IDL as selectable primary and alternate links could provide the communication network needed for the UAV systems interoperability.

3. A notional concept of the data link interconnectivity is depicted in Figure 15 on the following page.

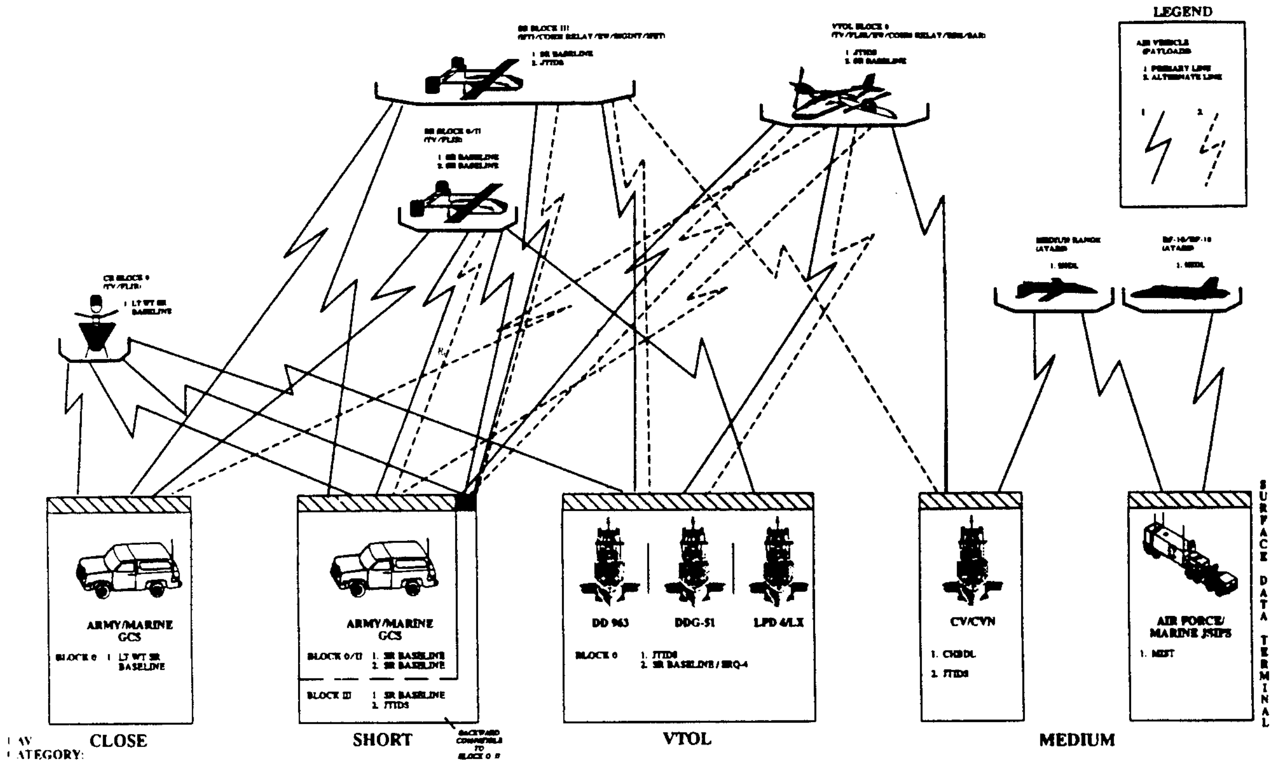


Figure 15 Interoperability Data Link Subsystem Concept

The family of air vehicles with various airborne data terminals (ADTs) are depicted at the top and associated surface data terminals (SDTs) are shown at the bottom. Primary and alternate communication paths are indicated between ADTs and SDTs for each UAV category and between different categories.

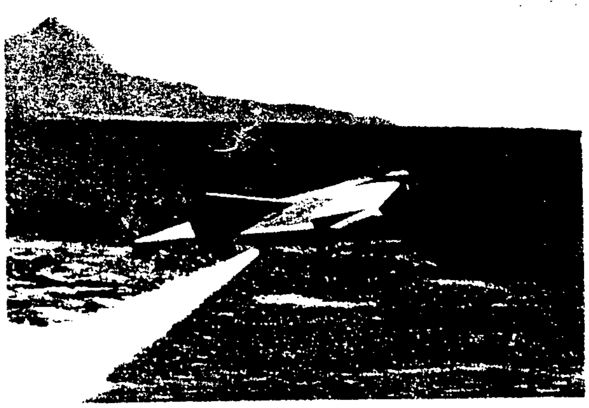
VI UNMANNED AERIAL VEHICLES JOINT PROJECT OFFICE (UAV JPO) PROGRAMS

A. VERY LOW COST (VLC)

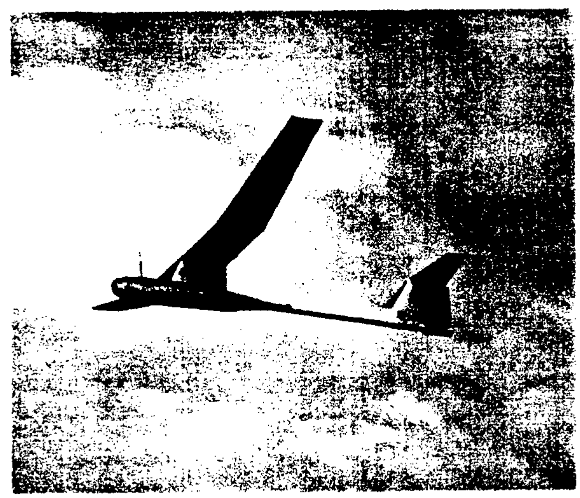
VLC UAV systems are used to demonstrate and evaluate the utility of UAVs in battalion and sub-battalion tactical units (e.g., company, platoon, squad, and special operations team). They also allow for operational experimentation that assists in requirements definition and refinement prior to procurement. They are very easy to launch, recover and operate, and require a minimum of operator maintenance and training.

The USMC UAV Program Office, part of the Marine Corps Systems Command, Quantico, VA has recently completed the first phase of the FQM-151A Pointer demonstration and is managing programs for the BQM-147A EXDRONE (see Figure 16) and a VLC UAV for counternarcotics applications in support of the DEA. See Section VII B, E, and F for further discussion.

Although the first phase report on Pointer determined that the existing system was not suitable for Service use, the USA has expressed interest in continuation of Pointer demonstrations to gain further insights into UAV employment concepts. Additionally, a demonstration with the Unmanned Ground Vehicles Joint Project Office is also planned for July 1992.



EXDRONE



Pointer

Figure 16 VLC UAVs

B. CLOSE RANGE (CR)

The CR acquisition strategy is to procure a cost effective system consisting of integrated off-the-shelf technologies with a high degree of I&C with the SR system, as the baseline for the family of UAVs. The CR system will provide near-real-time RSTA capabilities out to 30 km beyond the FLOT that meet the requirements of USA and USMC commanders at division and subordinate levels of command. The CR UAV baseline system deployment is shown in Figure 17.

The CR concept, system requirements, and acquisition/risk management planning have been significantly influenced by SR progress, formal studies, experimentation with existing domestic and foreign systems, budget realities and lessons learned during Desert Storm.

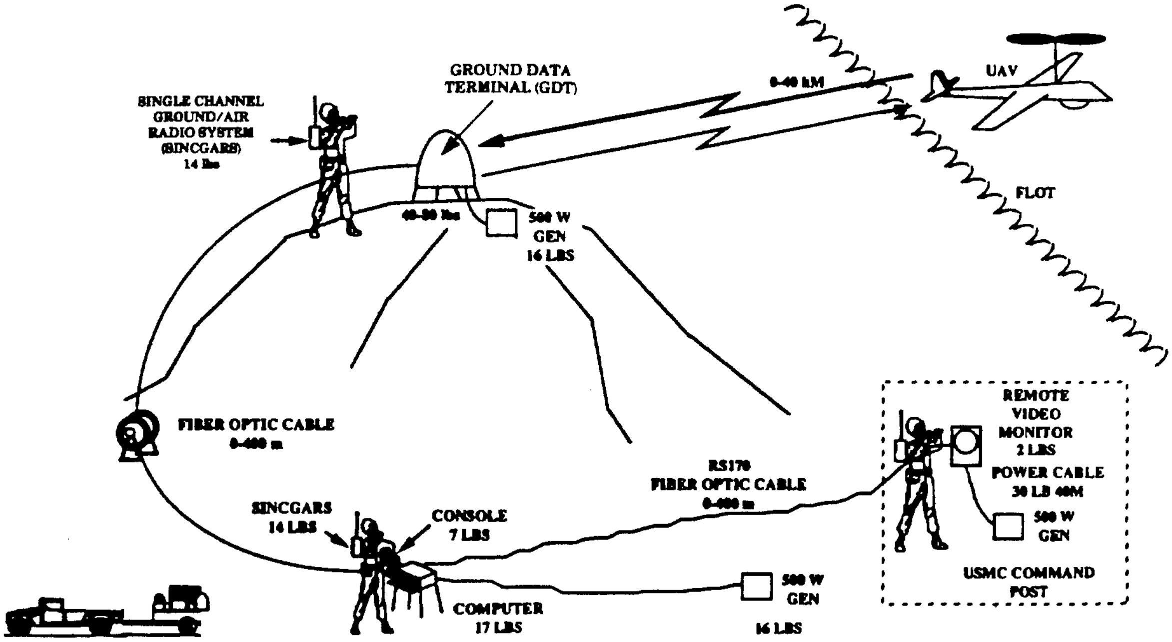


Figure 17 CR UAV Baseline System Deployment

The CR notional system definition is shown in Figure 18. The equipment to be fielded with the USMC to support the MAGTF consists of a small UAV with a day/night sensor and meteorological sensors controllable from a portable ground control station (GCS). This system will be operable by two service personnel, and will be transported on a single high mobility multipurpose wheeled vehicle (HMMWV) and standard trailer. The system will also be fielded with the USA at the division and brigade level as the launch/recovery section and will be augmented with a GCS and associated hardware from the SR system. This will provide maximum C^3I commonality/interoperability to support the USA's battlefield operations.

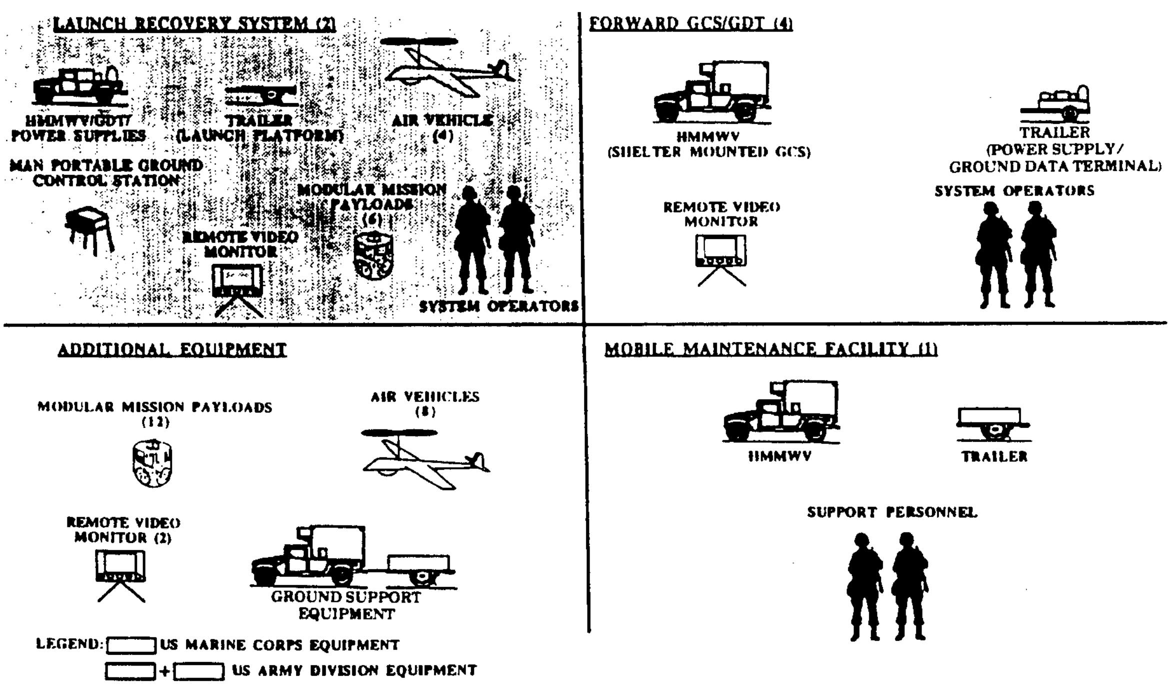


Figure 18 CR Notional System Definition

The employment concept for this augmented system is to perform launch, recovery, handling, and initial/terminal flight operation from rear areas, while mission planning/control and data distribution will be handled in forward areas (See Figure 19).

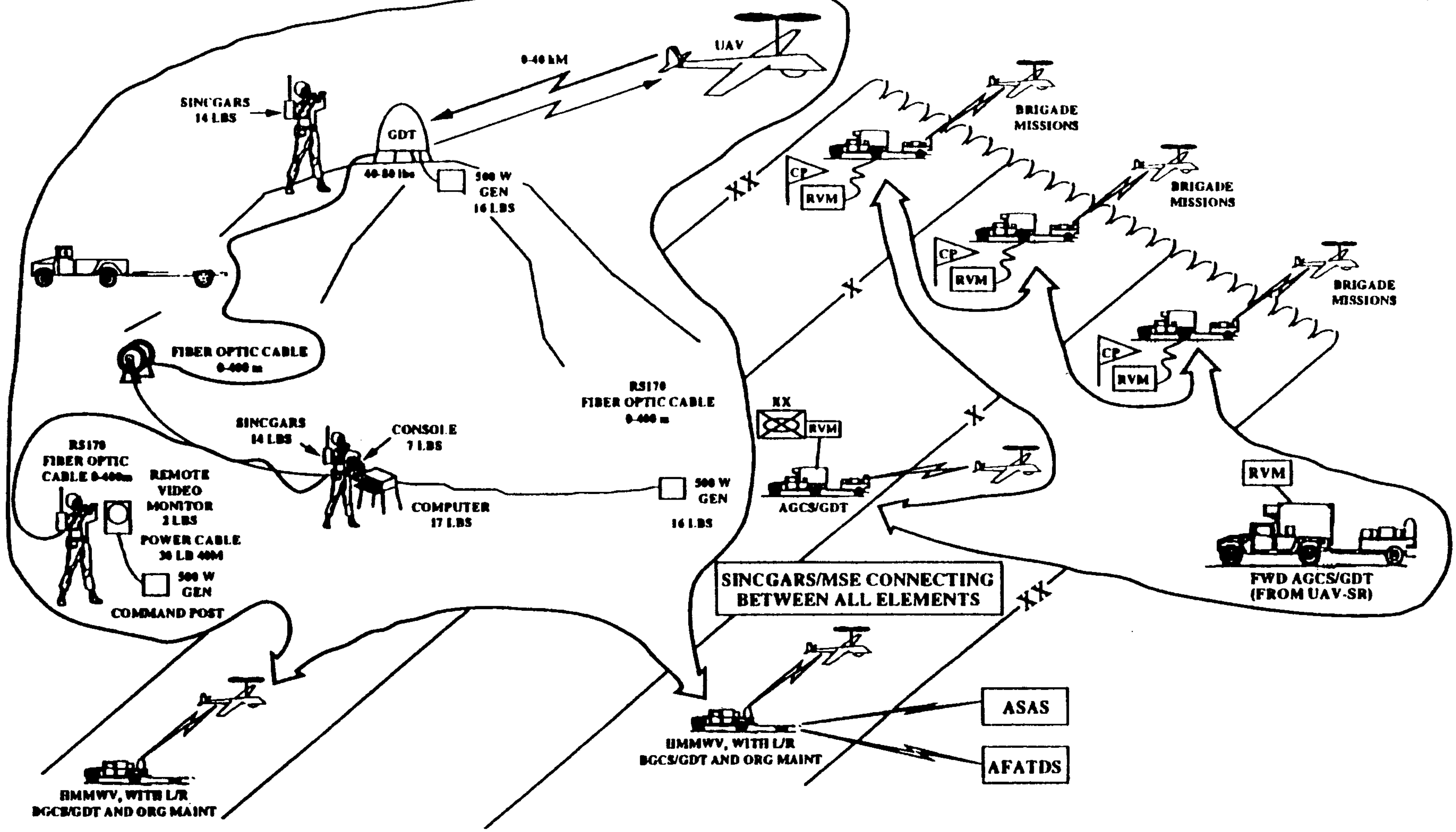
In order to maximize I&C, SR common hardware and associated software will be utilized in the CR system. The SR GCS, ground data terminal (GDT), and ADT will be downsized and used in the CR system. This strategy requires that three contracts be awarded during the engineering and manufacturing development (E&MD) phase. Two of these contracts will be for SR common hardware and SR downsized hardware. The third contract, for the CR prime contractor, will be awarded after full and open competition. The CR prime contractor will be responsible for system integration, air vehicle development and CR peculiar equipment.

The CR program schedule (see Figure 20), will be streamlined by concurrent production of design and LRP prototypes. A critical design review (CDR), which establishes the system design, will provide the basis for approval to exercise the contract option for LRP. Following the CDR, two LRP prototype units will be produced concurrently with the production of two design prototypes. The streamlined schedule will make it possible to provide a CR system to the user in an expeditious manner, and will not greatly increase risk.

Risk, inherent in any design process, will be reduced by the integration nature of the development contract. Technologies to be integrated will be sufficiently mature in that redesign will be minimized. Technical data already available reflects that existing air vehicle technologies can satisfy CR system needs with little modification.

CR demonstrations conducted in FY92 will demonstrate that CR type air vehicles and payloads are capable of performing within the technical parameters required for the CR system. Contracts have been awarded to six contractors for technical demonstrations of 200 lb. class air vehicles, and to four contractors for light weight FLIR systems. One of the FLIR contractors has since been dropped by the technical demonstration program. These demonstrations provide a forum for identifying any potential problems which might affect schedule or technical performance, and further decrease risk. See Section VII C for further discussion.

The USD(A) has designated the CR program as one of four to participate in a Defense Acquisition Pilot Program in accordance with public Law 101-510, Section 809, Title 10 United States Code 2436. These programs will be conducted in accordance with standard commercial/industrial practices, with the objective of identifying the potential for increasing the efficiency and effectiveness of the acquisition process.



LEGEND

AFATDS	— ADVANCED FIELD ARTILLERY TACTICAL DATA SYSTEM	BGCS/GDT	— BASELINE GROUND CONTROL STATION/GROUND DATA TERMINAL
AGCS/GDT	— AUGMENTED GROUND CONTROL STATION/GROUND DATA TERMINAL	CP	— COMMAND POST
ASAS	— ALL SOURCES ANALYSIS SYSTEM	FWD	— FORWARD
		GEN	— GENERATOR
		HMMWV	— HIGH MOBILITY MULTIPURPOSE WHEELED VEHICLE
L/R	— LAUNCH/RECOVERY		
MSE	— MOBILE SUBSCRIBER EQUIPMENT		
RVM	— REMOTE VIDEO MONITOR		
SINCGARS	— SINGLE CHANNEL GROUND/AIR RADIO SYSTEM		

Figure 19 CR Augmented System Deployment

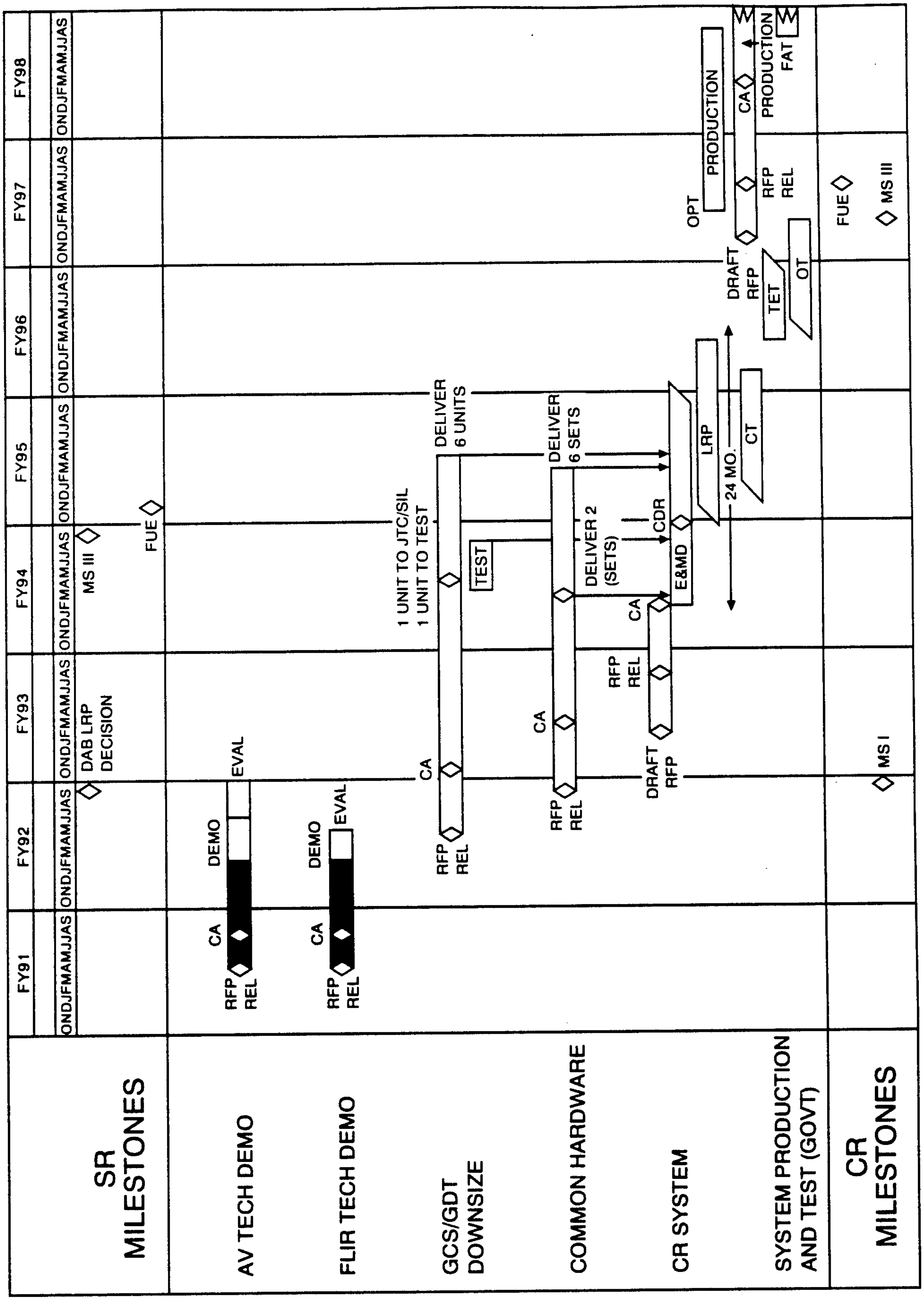


Figure 20 CR UAV Program Schedule

C. SHORT RANGE (SR)

The SR system is the developmental baseline for the family (i.e., SR, CR, VTOL, and Endurance) of UAVs. SR will provide near-real-time RSTA to USA echelons above corps (EAC), divisions and USMC expeditionary brigades out to 150 km beyond the FLOT, day or night, and in limited adverse weather conditions. SR is intended for employment in environments where immediate information feedback is needed, manned aircraft are unavailable, or excessive risk or other conditions render use of manned aircraft less than prudent. The SR concept of operations (CONOPS) is shown in Figure 21.

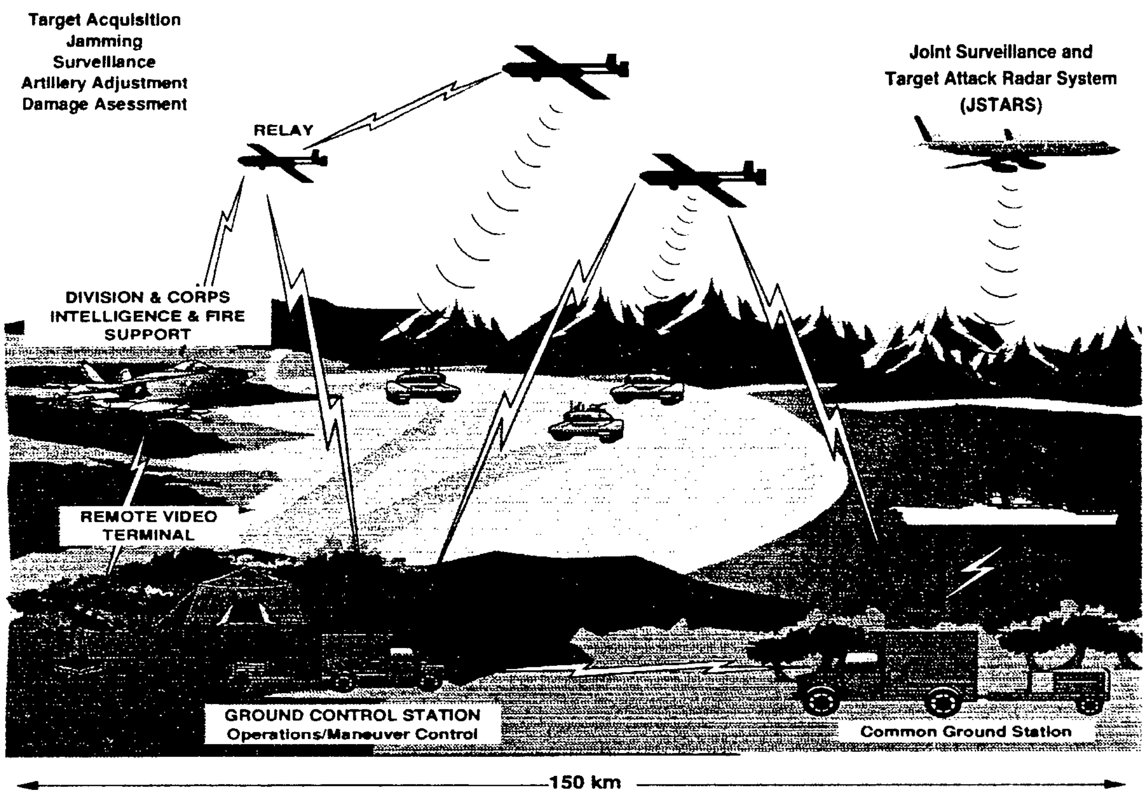


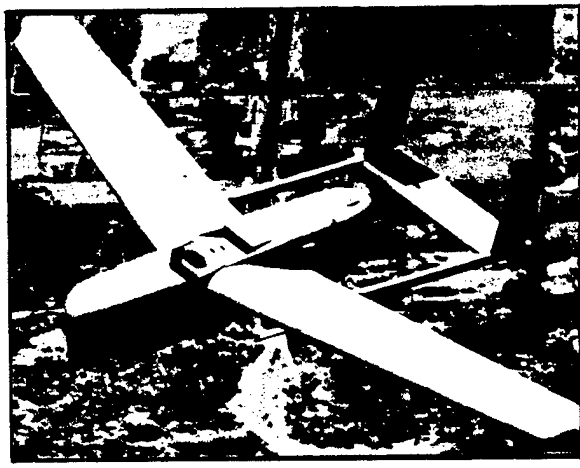
Figure 21 SR Concept of Operations

The SR acquisition strategy ensures interoperability and maximizes commonality, including the fielding and evaluation of an initial baseline configuration, followed by block upgrades to meet the full operational requirements. A modular approach incorporating standard architecture facilitates upgrades and provides a flexible baseline for other systems. The SR system takes maximum advantage of existing off-the-shelf technologies.

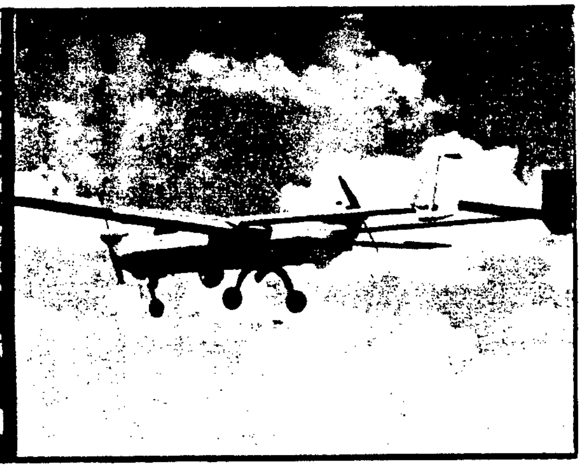
Acquisition of the SR system began with full and open competition in FY89. A draft request for proposal (RFP) was provided to industry in December 1988, followed by a formal RFP in March 1989. Contractors submitted proposals based on the award of a fixed price incentive contract for the production of two integrated SR systems for testing and not-to-exceed price options for three production lots in FY92, FY93, and FY94.

On evaluation of the responses from industry, two firm-fixed price contracts were awarded on 15 September 1989 to McDonnell Douglas Missile Systems Company

(MDMSC), St. Louis, MO, and Israeli Aircraft Industries Ltd. (IAI), Tel Aviv, Israel (See Figure 22). The contractors were allotted 18 months for fabrication and integration of their systems and delivery of complete SR systems and other associated hardware for TET and LUT I. Additionally, both contractors have submitted, as required, concepts for SR Block I and II upgrade improvements. Block I is now managed separately as the VTOL UAV program (see Section VI D).



McDonnell Douglas



Israeli Aircraft Industries

Figure 22 SR UAVs

Prior to completion of the testing phase, the contractors will submit proposals for the design, fabrication, and test of Block II upgrades. Based on evaluation criteria of cost, technical characteristics, logistics, and management, a down selection to a single contractor will occur prior to the DAB LRP decision. After the DAB, LUT II will be conducted on production representative equipment to examine the operational suitability of the selected system when operated and maintained by typical military users. The MS III full rate production (FRP) decision will be supported by an Initial Operational Test and Evaluation (IOT&E) conducted on LRP hardware.

TET of the MDMSC and IAI candidate SR UAV systems began on 15 July 1991. As of the 6 October 1991 scheduled completion of TET flights, insufficient data had been accumulated to validate that the contractor candidate systems were ready for LUT I. The program schedule was therefore adjusted to allow a resumption of TET flights from January through April 1992 in order to accumulate sufficient data to certify the systems for LUT I. The DAB LRP decision is scheduled for 4th quarter FY92, and the MS III FRP decision will be sought 4th quarter FY94. (This information is shown in Figure 23, SR UAV Baseline Program Schedule).

The SR system consists of a MPCS, which includes one mission planning station (MPS) and two GCSs; remote video terminals (RVTs); eight air vehicles; modular mission payloads; ground and air data terminals; launch and recovery equipment; and integrated logistics support (ILS). The SR UAV employment concept is shown in Figure 24.

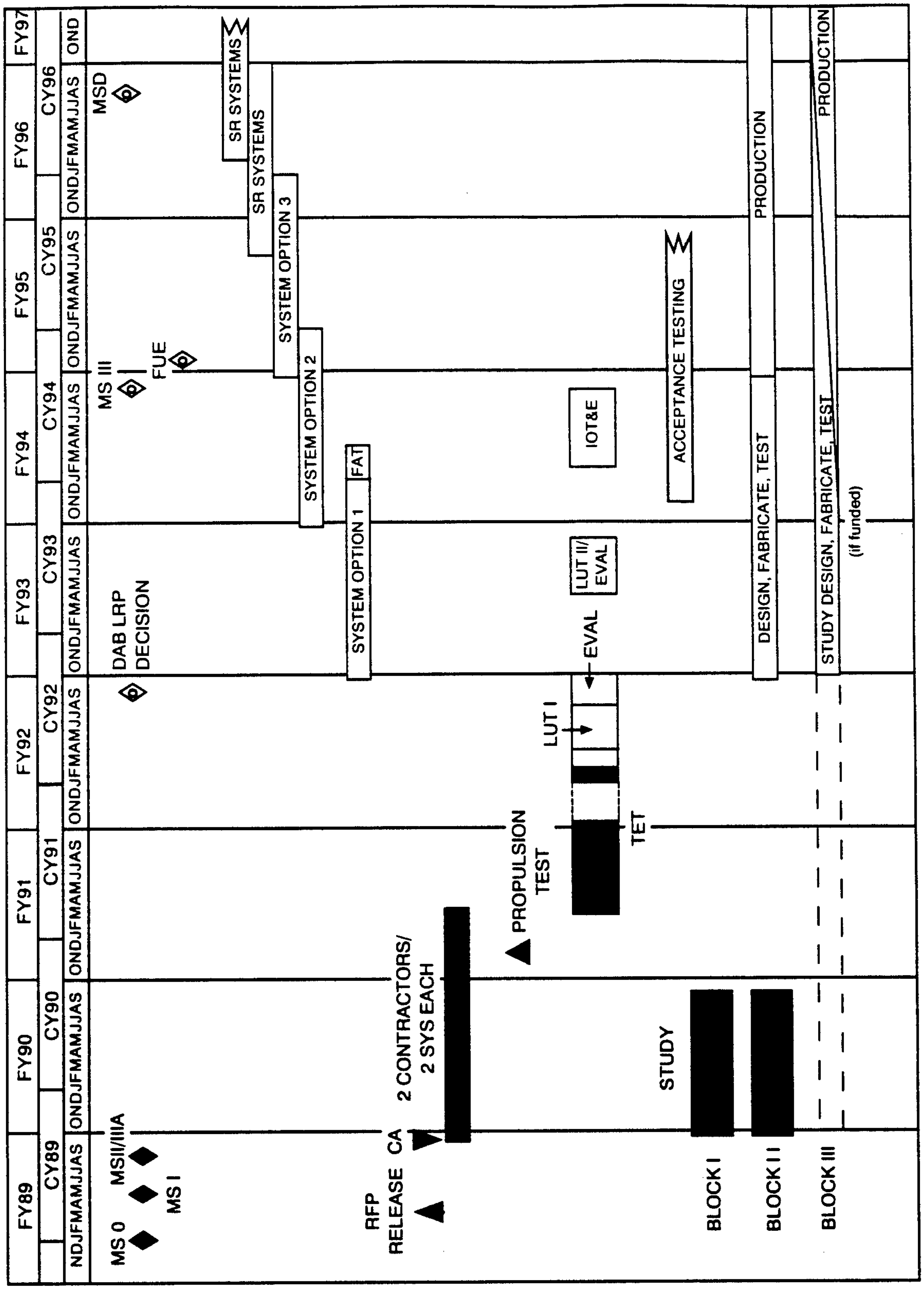


Figure 23 SR UAV Program Schedule

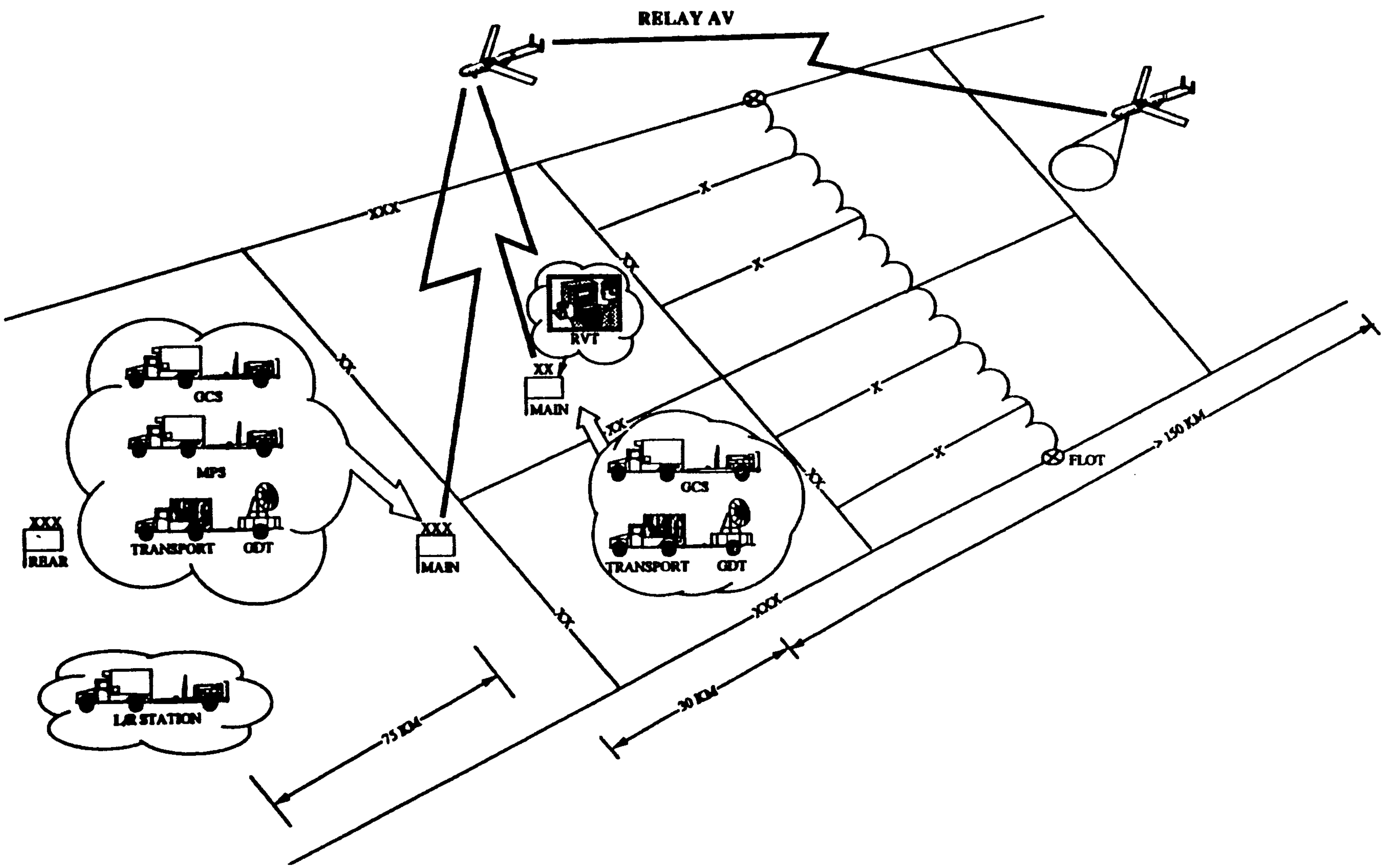


Figure 24 SR UAV Employment Concept

The MPCS collects, processes, analyzes, and stores data and distributes battlefield information by interfacing with present/planned Service C^3I systems. Flight and mission commands are sent through ground data terminals to the air vehicle and modular mission payloads from the MPCS. RSTA information and air vehicle position data are sent by downlink either through airborne relays or directly to the MPCS and external receiving systems . Mission data may also be recorded onboard the air vehicle to prevent loss during interruptions in the downlink data flow. Data are received by the MPCS and can be distributed to RVTs located in tactical operations centers. Mission capability will be enhanced as advanced mission payloads which are discused below become available.

Block II upgrades are options in the existing contracts with MDMSC and IAI. The Block II option will be exercised only with the winning SR prime contractor to avoid dual development costs. This strategy reduces cost but still achieves the requirements of the SR MNS. The Block II contract option will be exercised along with the LRP option upon downselect to the winning SR prime contractor (See Block II schedule at Figure 25). Block II modification kits are planned to be purchased so that all Block 0 (baseline) systems can be upgraded.

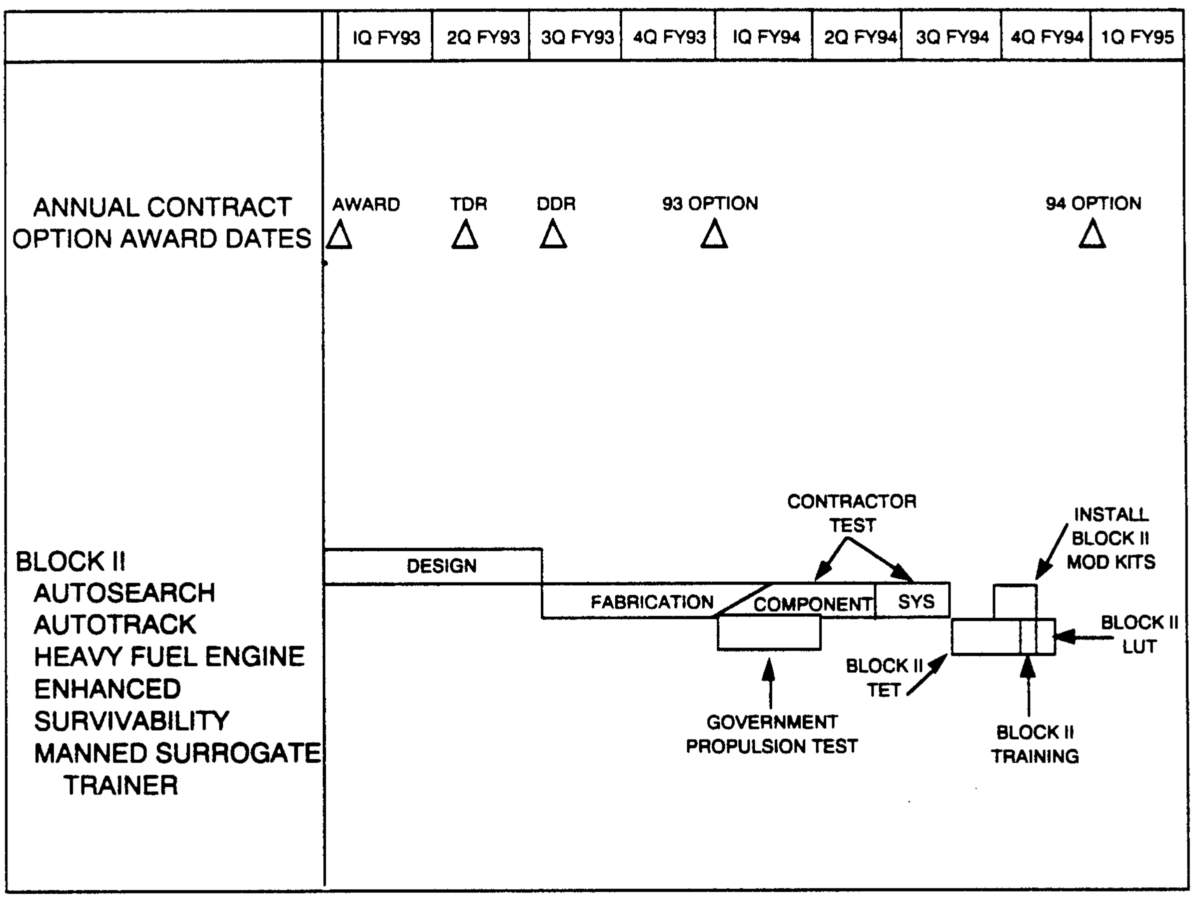


Figure 25 SR UAV Block II UAV Schedule

The specific improvements comprising Block II are as follows:

Autosearch - Automatic pattern search of designated area.

Autotrack - Capability of automatically holding the air vehicle's sensor line-of-sight on a designated target.

Heavy Fuel Engine - Capability of the air vehicle engine to operate on JP-5, JP-8, or diesel fuel.

Enhanced Survivability - Cost effective additions to the air vehicle to reduce signature, provide decoys for radar guided missiles, provide random maneuvers, and to minimize single point failures.

Manned Surrogate Trainer - Allows the system to operate with a manned UH-60 helicopter carrying a sensor pod to provide mission training in restricted areas.

The SR program also includes Block III government activities (not part of the SR contracts) that address advanced development, prototyping, and testing needed to incorporate additional required sensor payloads, C^3 upgrades, survivability improvements, air vehicle anti-icing, and data link hardening. Block III will capitalize on hardware funded and developed by other activities. Block III priorities have been established based on user needs and technology availability. The plan and schedule for Block III improvements are shown below and in Figure 26. Both are subject to change based on FY93 and FY94 fiscal decisions. Additionally, payload priorities may change based upon the results of the SSG Payload Working Group as discussed in Section V D.

FY93 - 94	FY95 - 96	FY97 and Beyond
Battlefield communication and data distribution	Radar payload	Meteorology II payload
Automatic landing	Survivability	Multiple air vehicle sensor operations
Meteorology I payload		Lightweight hardened data link
Communication relay (airborne) payload		
EW jamming payload		
SIGINT payload		
Air vehicle icing detection/removal		

	FY93	FY94	FY95	FY96	FY97	FY98	FY99
BLOCK III							
BATTLEFIELD COMMUNICATION AND DATA DISTRIBUTION	INTEGRATE/VALIDATE MODS IN JTC						
		DESIGN/INTEGT IMAGERY DISTRIBUTION & COMMO MODS		VALIDATE MODS IN JTC	CONTINUOUS IMPROVEMENTS		
AUTOMATIC LANDING	SELECT CONCEPT	INTEGRATE & VALIDATE					
METEOROLOGY I	DESIGN REQMNTS/INTEGRATE PREPARE SPECS		TRANSITION TO CONTRACTOR				
COMMUNICATION RELAY	DESIGN REQMNTS/INTEGRATE PREPARE SPECS		EVALUATE IN JTC/SIL TRANSITION TO CONTRACTOR				
EW (JAMMING)	DESIGN REQMNTS/INTEGRATE PREPARE SPECS		EVALUATE INTERFACES IN JTC/SIL	DEVELOP SPEC TRANSITION TO CONTRACTOR			
AV DEICING SYSTEM	INVESTIGATE AND TEST PROPOSED IMPROVEMENTS		SELECT UPGRADES DEVELOP SPECS	VALIDATE IN JTC/SIL TRANSITION TO CONTR			
RADAR PAYLOAD			INVESTIGATE DEV. PAYLOAD	INTEGRATE PREPARE SPEC	CONSTRUCT PRO-TOTYPE TEST IN JTC	TRANSITION TO CONTRACTOR	
SURVIVABILITY		COST-EFFECTIVE ANALYSIS		INTEGRATE/TEST MODS			
SIGINT	INVESTIGATE AND SELECT NDI INTEGRATE		PREPARE SPEC/PRO-CURE PROTOTYPE	EVALUATE IN JTC			
METEOROLOGY II					SELECT & ADAPT TECHNOLOGY	INTEGRATE	TRANSITION TO CONTRACTOR
MULTIPLE AV/ SENSOR OPERATION					EVALUATE CONCEPTS IN JTC	DEVELOP SUBPROGRAMS	
LIGHT WEIGHT ANTI-JAM DATA LINK					EVALUATE NDI UNITS IN JTC	INTEGRATE & VALIDATE	

Figure 26 SR UAV Block III Upgrade Summary

D. VTOL UAV (Not presently resourced)

The VTOL UAV, formerly the Maritime UAV, will provide an organic, unmanned, over the horizon RSTA and ship self defense capability for expanding battle space of surface combatants. The air vehicle will be capable of VTOL to minimize deck impact and interference with shipboard helicopter operations. The system will conduct extended operations in a maritime environment, during inclement weather and in moderate sea states. The salient requirements stated in the ORD are shown in Figure 27. The ORD was promulgated by the USN on 21 February 1992, is in Service coordination, and will be forwarded to the JROC SSG for validation.

SURFACE COMBATANT OVER THE HORIZON SURVEILLANCE AND TARGETING; ANTI-SHIP MISSILE DEFENSE SUPPORT

REQUIREMENT		DRIVER
Radius of Action -	110 nm	Harpoon Targeting, Battle Damage Assessment (BDA)
Speed -	135 Knots Cruise	Acquire, Reacquire, Mission
Loiter on Station -	3 Hours, at 110 nm	Tactical Air-Surface Missile (TASM) Support
Operating Altitude -	12,000 ft	Line of Sight (LOS) at 110 nm
Sensors -	ECM, Imagery	Air-Surface Missile Defense (ASMD), RSTA, BDA, Naval Ship Fire Support (NSFS)
Air Vehicle Type -	VTOL From/To Helo Spot	Ship Compatibility
Data Link -	Ship Topside Compatible	Ship Electomagnetic Environment
Growth Payloads -	Radar	RSTA Search Rate
	Data Relay	Beyond LOS Operations

Figure 27 VTOL UAV Requirements

The VTOL UAV missions of over the horizon targeting (OTH-T), naval ship fire support (NSFS), battle damage assessment (BDA) and ship classification will generally be performed 80 to 110 nm from the host ship. These missions will task the air vehicle to search a designated area to confirm and more precisely geolocate a suspected target, usually with imagery for positive identification and BDA. Notional operational scenarios are depicted in Figure 28.

The VTOL UAV system concept focuses on integrating SR UAV system software and hardware into DDG-51 subsystems which will be modified or adapted for the maritime system applications. The air vehicle will be a high speed VTOL capable of meeting the speed, endurance and payload requirements of the ORD. The air vehicle will carry imaging sensors common with the SR and CR UAV programs and will incorporate the SR video downlink to ensure interoperability. SR system software will be hosted on an existing DTC-II type processor in the ship's operations center to accomplish mission planning, air vehicle control and data exploitation functions.

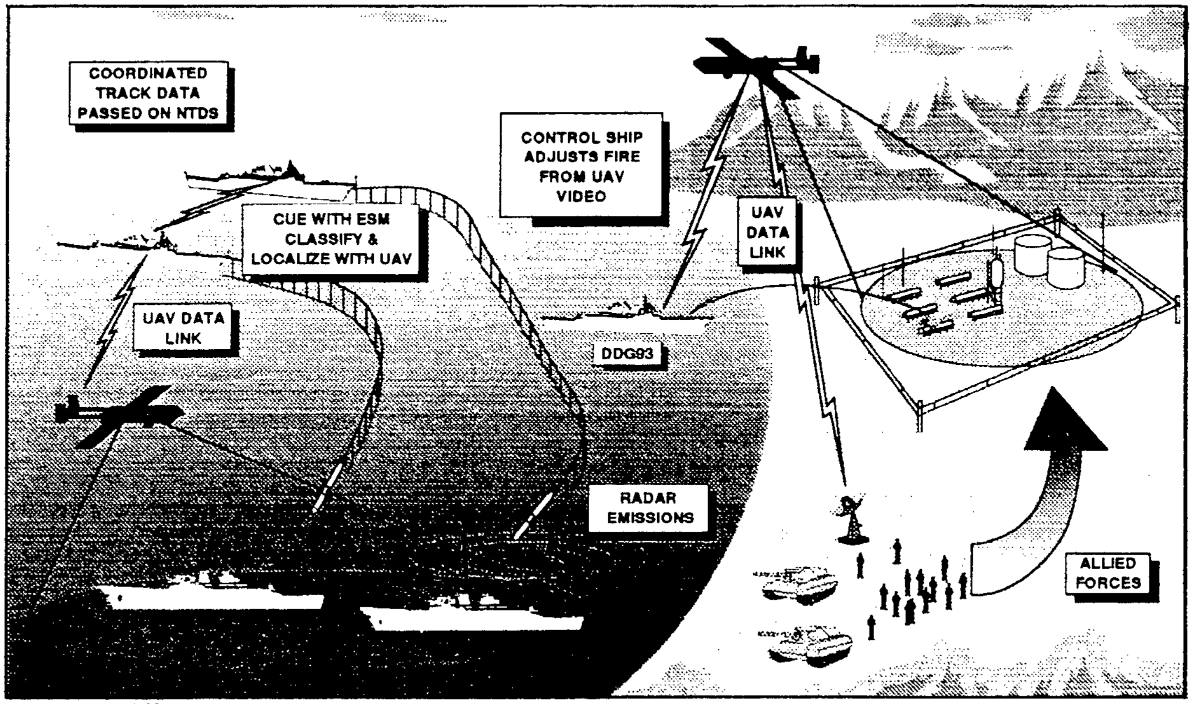


Figure 28 VTOL UAV Operational Scenario

Because of the unique operating environment, the VTOL UAV will require its own launch and recovery equipment. The VTOL system concept by subsystems is shown in Figure 29.

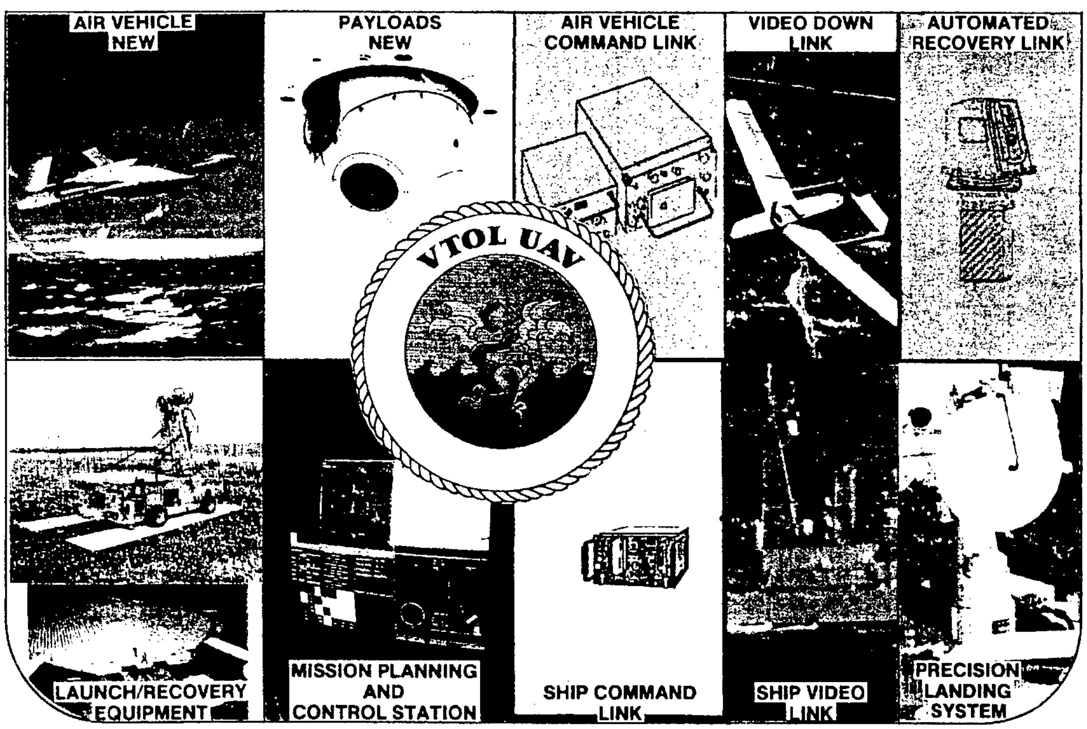


Figure 29 VTOL UAV System Concept

Although the VTOL UAV is a high priority with the JROC and the USN, the absence of a finalized ORD precluded requesting funds for this program in the FY92 budget cycle. Funding is being requested in the FY93 budget and the FY94 POM for a risk reduction program described in Figures 30, 31 and 32.

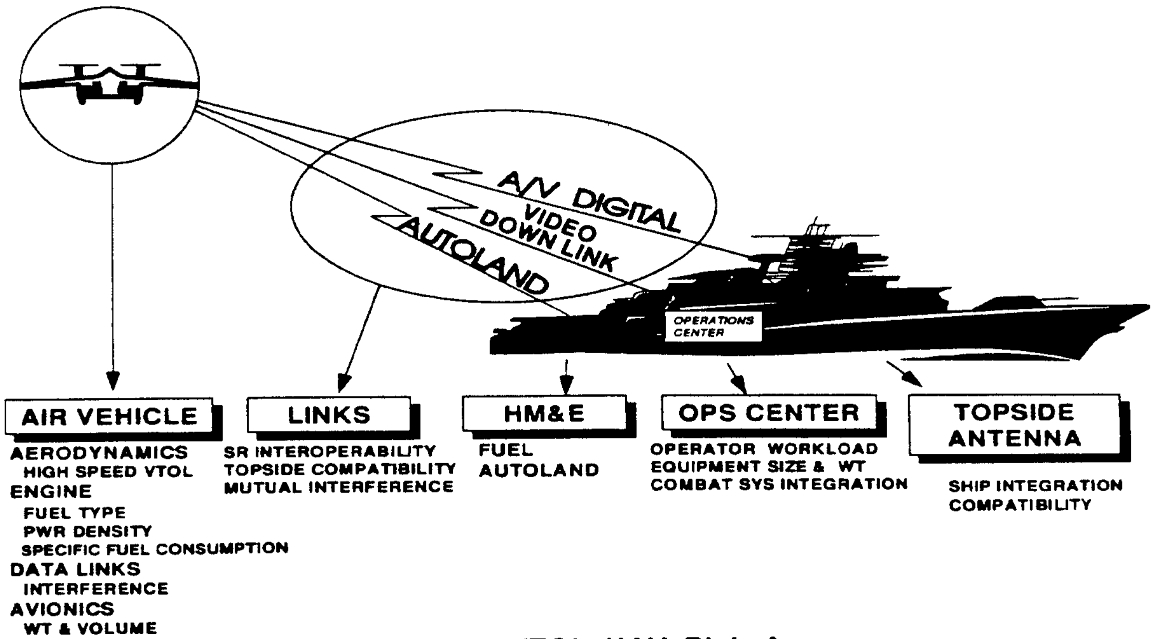


Figure 30 VTOL UAV Risk Areas

- AIR VEHICLE DEMONSTRATIONS
  - Brayton Cycle Engine
  - Maritime Vertical Takeoff and Landing UAV System (MAVUS)
  - Tilt Rotor UAV Flying Demo
  - Slave Tandem Free Wing Flying Qualities
  - Core Avionics Flight Demonstration
  - SR Flight with "Ship System"
  - Heavy Fuel Engine Demonstrations

- DATA LINKS
  - SR UAV Imagery Via SRQ-4 System
  - SR UAV Control Via Link 16 System
  - Data Link Compatibility Demonstration

- HULL, MECHANICAL & ELECTRICAL DEMONSTRATIONS
  - MAVUS
  - Dornier Autoland Demonstration
  - Sierra Nevada Autoland Demonstration
  - Heavy Fuel Engine Demonstration

- OPERATIONS CENTER DEMONSTRATIONS
  - SR S/W Operate on DTC-II Advanced Tomahawk Weapon Control Station
  - Flight Demo With SR UAV
  - Operator Workload Demonstration

Figure 31 VTOL UAV Risk Reduction Program

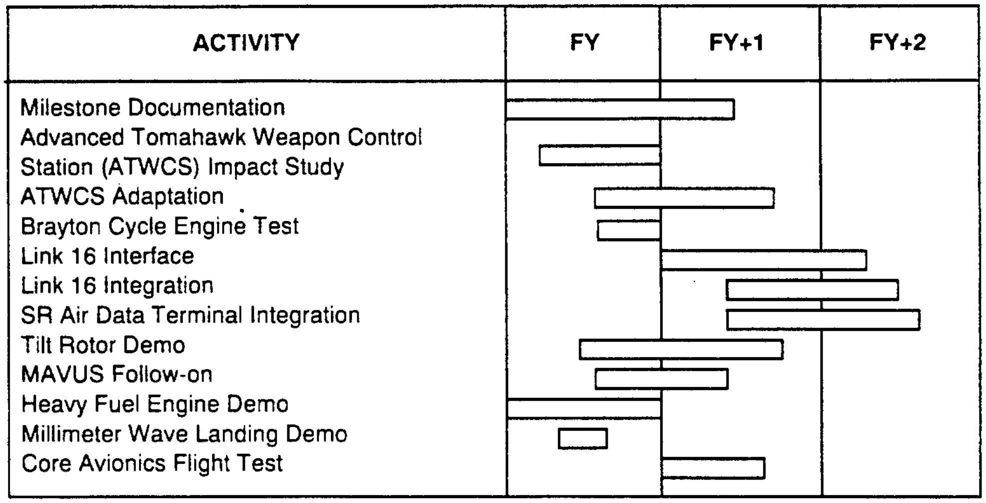


Figure 32 VTOL UAV Technology Demonstration Schedule

E. MEDIUM RANGE (MR)

The MR UAV, designated BQM-145A, (see Figure 33) is being developed to perform USN, USMC, and USAF reconnaissance missions in the late 1990s and beyond.

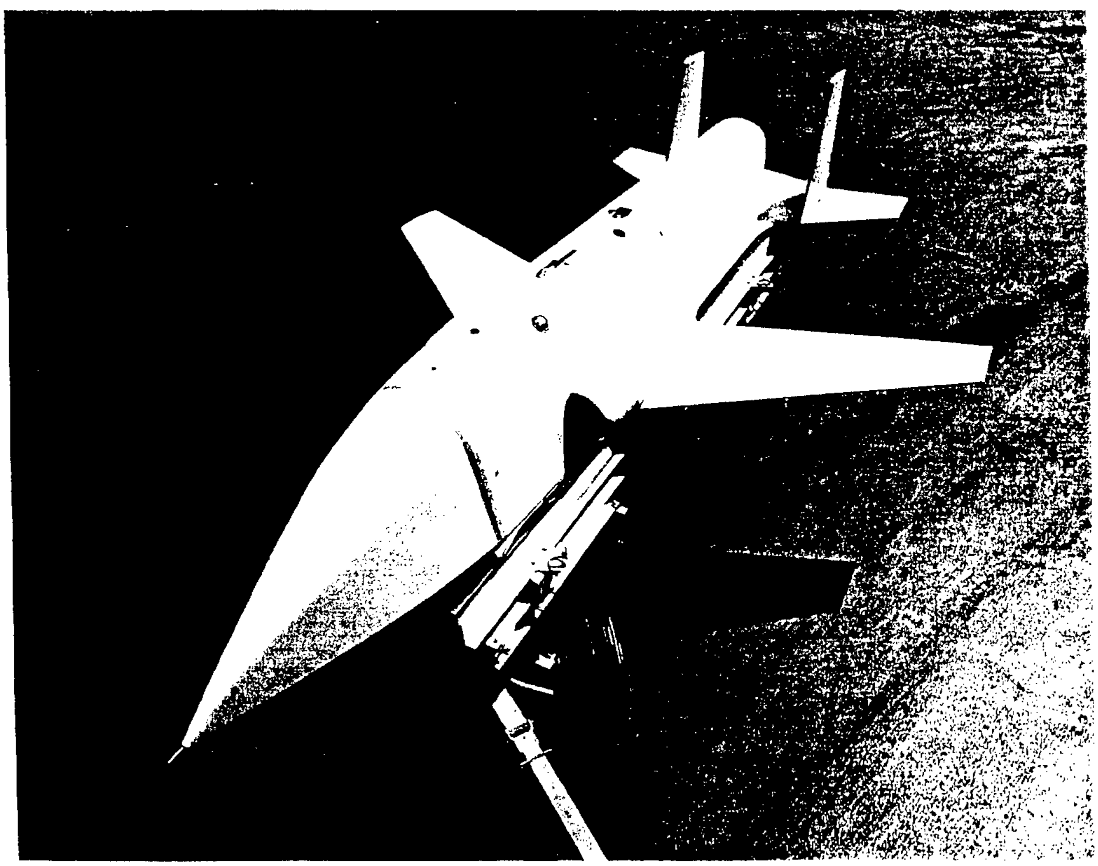


Figure 33 BQM-145A MR UAV

A complementary asset to manned tactical reconnaissance, it will provide a quick response capability to obtain high quality imagery in high threat environments. The system provides multi-function support to the C^3I operations of Carrier Battle Groups (CVBGs), MAGTFs, and Tactical Air Force (TAF) units, with target acquisition (pre- and post-strike) and BDA being two of its primary missions. Upon creation of the UAV JPO, operational requirements of the individual Services were consolidated into a MNS approved June 1989. An ORD has been developed and is being staffed for approval; salient points are shown in Figure 34.

The MR UAV will be tasked to collect imagery data on fixed targets/locations at ranges up to 350 nm from launch point. The data will be of sufficient resolution and accuracy to support targeting for air and ground delivered weapons and to provide BDA.

Radius of Action	650 km (350 nm)
Speed	0.9 mach number
Operating Altitude	500' AGL to 40,000' MSL
Navigational Accuracy	25 meters CEP
Imagery Resolution	> NIIRS (National Imagery Interoperability Rating Scale) -4
Capable of Air & Ground Control	F/A-18D, F-16R & Surface Launcher
Mission Planning	TAMPS (USN/USMC) & Air Force Mission Support System (AFMSS)
Data Exploitation	JSIPS & JSIPS-N
Growth Payloads	EW, Comm/Electronic SIGINT Meteorological, Target Designation

Pre and Post-Strike Reconnaissance; Battle Damage Assessment

Figure 34 MR UAV Requirements

Typically, the MR UAV will fly high risk missions in heavily defended areas where the severity of the threat makes assigning the mission to manned tactical reconnaissance aircraft undesirable. Figure 35 depicts a notional MR UAV operational scenario.

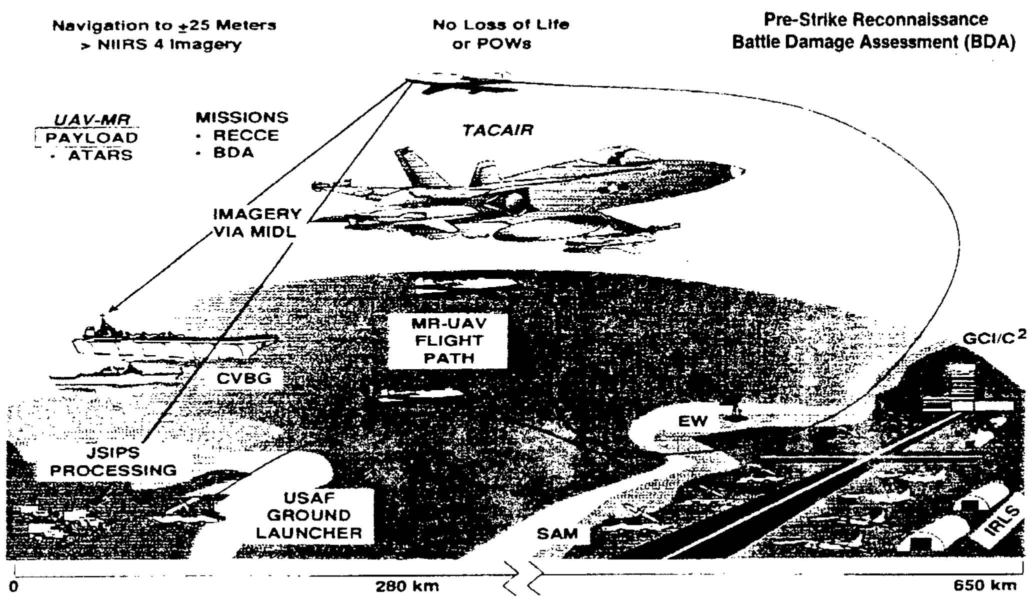


Figure 35 MR UAV Operational Scenario

The MR UAV acquisition strategy emphasizes harmonization of Service requirements and the commonality and standardization of system hardware, software, training and ILS. The system concept focuses on interoperability with Service common mission planning and data exploitation systems. MR UAV operational interfaces are shown in Figure 36.

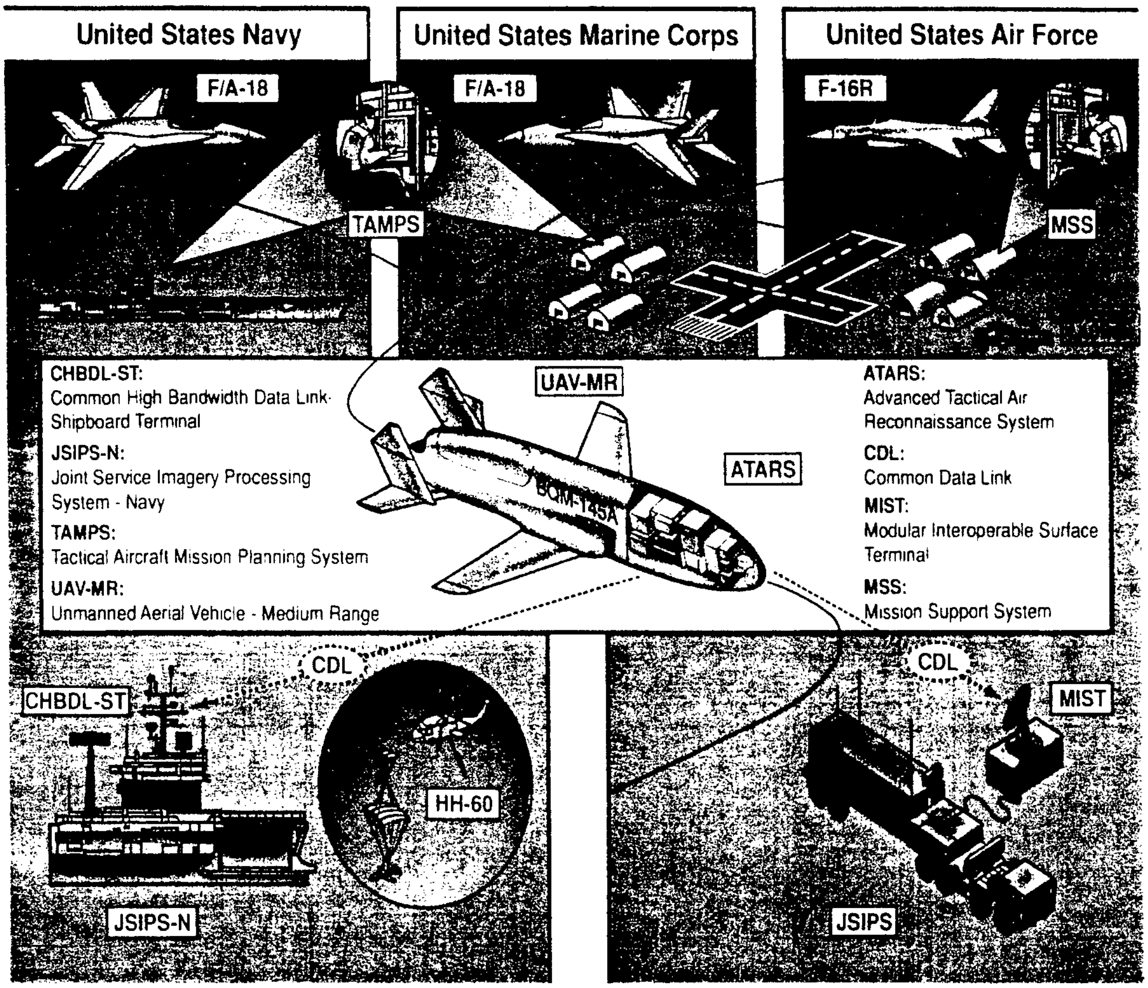


Figure 36 MR UAV Operational Interfaces

Recently redefined, the MR UAV program is comprised of four phases. Phase I is a risk reduction effort and consists of CFT-I using composite structure vehicles. Phase II, using metallic air vehicles, starts with government flight testing (GFT-I) and extends to multi-Service operational test & evaluation (OT&E). Phase III commences with LRP and Phase IV is FRP. The overall program plan is depicted in Figure 37.

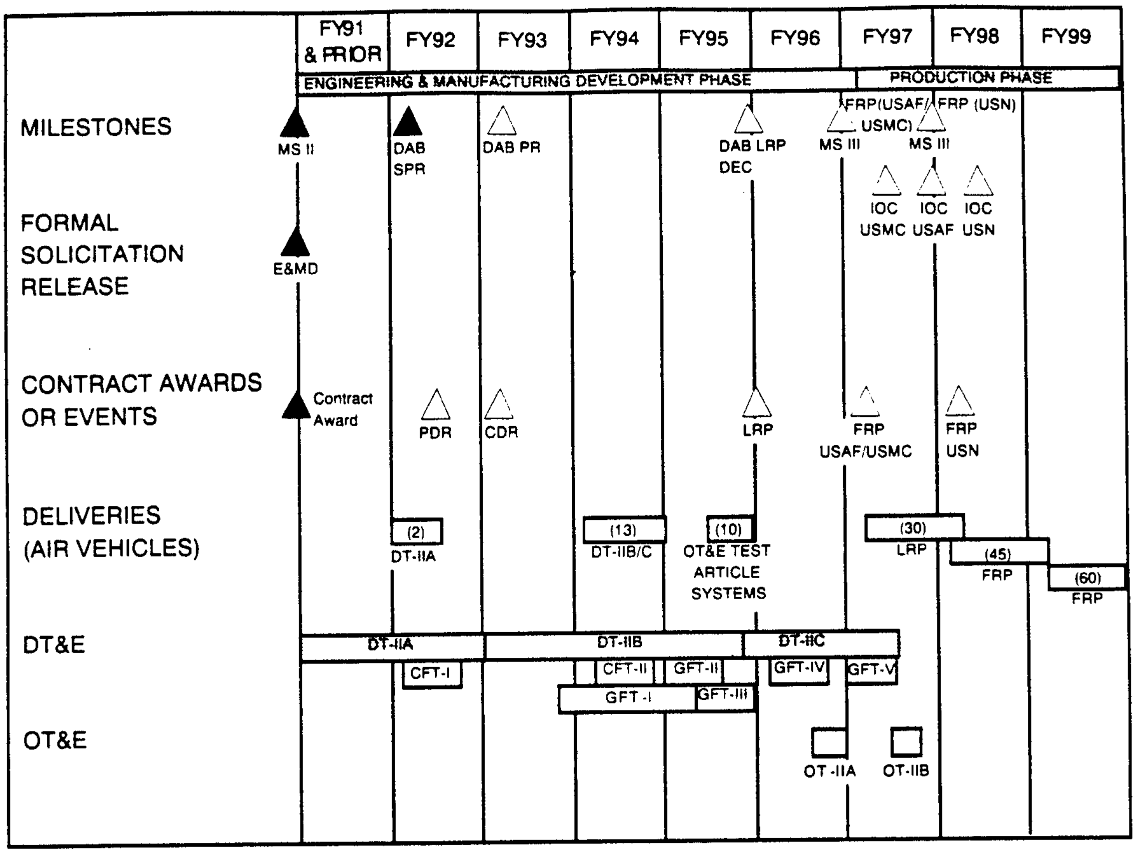


Figure 37 MR UAV Program Plan

F. ENDURANCE

The UAV SSG Working Group has initiated an effort to consider a requirement for an Endurance UAV that would be responsive to the needs of tactical commanders. The UAV JPO is assisting in this effort. At present the Defense Support Project Office (DSPO) has the responsibility for satisfying the requirements of the Endurance MNS.

G. COUNTERNARCOTICS

The UAV JPO is actively supporting efforts to establish a UAV capability in support of US Southern Command's (SOUTHCOM's) drug interdiction mission in Central/South America. Planning of the program is underway, but no funding is presently available. Effort involving the DEA is described in section VII F.

H. PIONEER

The Pioneer system provides near-real-time RSTA, BDA, and battlefield management within line-of-sight of its GCS, day or night. Pioneer can be employed on land, from battleships or from amphibious ships. Currently, plans are being developed to transition Pioneer from the battleships to an alternate ship class.

A Pioneer system consists of at least five air vehicles, a GCS, a portable control station, two remote receiving sets, and pneumatic or rocket assisted launchers. A Pioneer system is transported using two five-ton trucks and two HMMWVs with trailers.

Pioneer air vehicles are capable of operating for up to five hours with either day television or night FLIR sensors. Pioneer flies between 1,000 - 13,000 feet above sea level, 60 - 95 knots, and up to 220 km from a GCS. The air vehicle is driven by a pusher propeller and powered by a two cylinder engine using aviation gas. DoD has received the inventory objective of nine Pioneer systems: five systems for the USN, three for the USMC and one for the USA. Pioneer flight operations require about 20 personnel.

During Desert Storm, Pioneer UAVs flew over 300 missions. Only one air vehicle was shot down, and three others were hit by ground fire during combat missions. The phenomenal success of Pioneer in supporting combat operations and providing the battlefield commander critical intelligence information has shown the capabilities of UAVs within the battleforce structure. Figure 38 shows a Pioneer UAV taking off at Fort Huachuca, AZ.

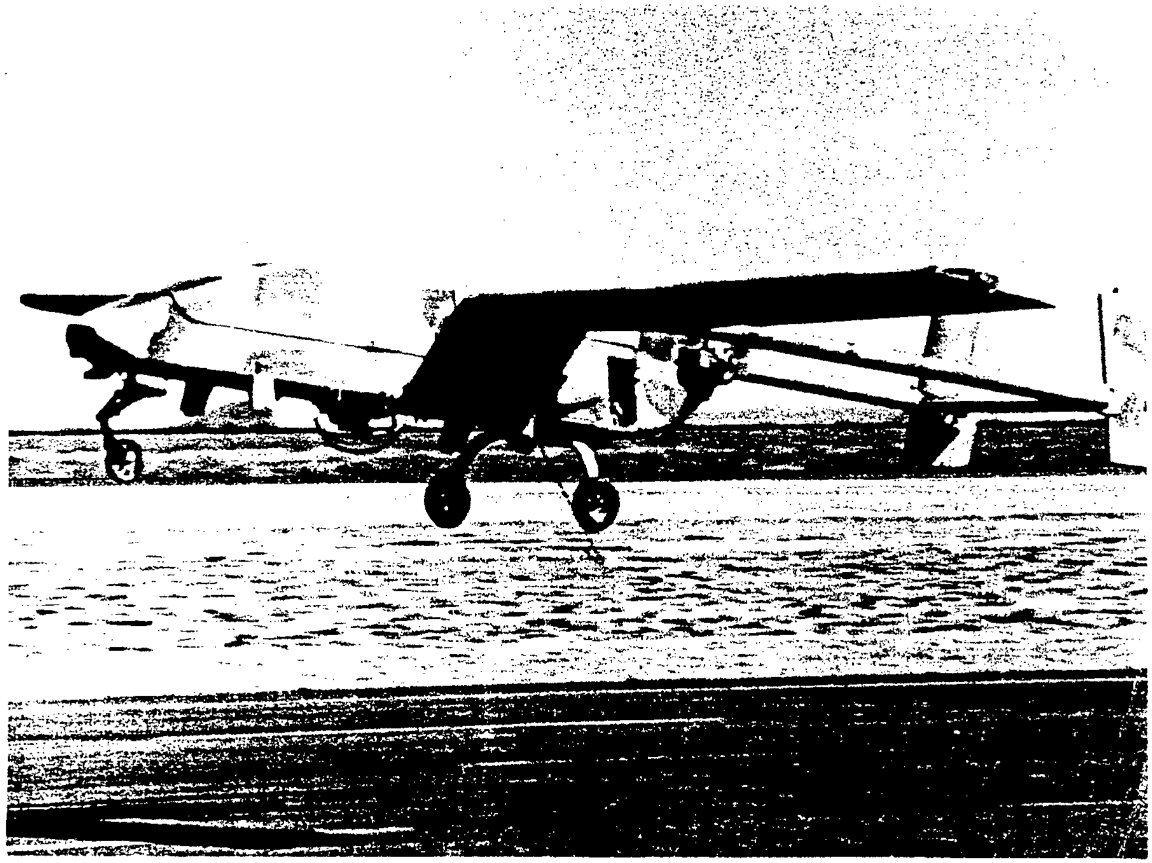


Figure 38 Pioneer UAV Taking Off

This capability and success has been confirmed by many of the operational commanders who were supported by the Pioneer UAV. The first surrender of enemy troops to a UAV took place on Faylaka Island, located just off of the coast of Kuwait City. Detailed video provided by the Pioneer UAV showing and locating fortifications in Iraq and Kuwait was instrumental to the success of attacks by coalition forces. BDA information collected by Pioneer for all types of ordnance was critical to the efficient

use of assets and determination of requirements for reattacks. One Pioneer unit flew about 150 hours in a one month period. These wartime operations were preceded by maritime interdiction force operations and surveillance along the Kuwait and Iraq borders during Desert Shield. See Section XIV for further discussion of Desert Storm activities.

Pioneer was introduced into the force structure in 1986. Since that time USN units have operated from four battleships during five deployments supporting world wide operations in Africa, Northern Europe, the Northern Atlantic, Korea, the Mediterranean Sea and contingency operations in the Persian Gulf. Marines have supported Weapons and Tactics Instruction and Kernal Blitz exercises as well as supporting the US Customs Service in drug interdiction missions. All three Services operated Pioneer in support of Operation Desert Storm. Since 1986 Pioneer units have flown approximately 6,600 flight hours in 3,100 flights. Pioneer is scheduled to operate through FY98, being gradually replaced by SR systems as they enter the force structure. Management of logistics, training, and test support for the Pioneer systems remains the responsibility of the UAV JPO.

VII DEMONSTRATIONS

A. CL-227 MARITIME VERTICAL TAKEOFF AND LANDING UNMANNED AERIAL VEHICLE SYSTEM (MAVUS)

The CL-227 UAV system includes a small, compact rotary-wing air vehicle capable of VTOL, hover and forward/reverse flight. The air vehicle carries modular mission payloads weighing up to 100 lbs. and flies at speeds from hover to 70 knots. Range is 60 km, maximum attainable altitude is 10,000 feet and flight endurance is up to three hours, depending on payload weight. The air vehicle (nicknamed "Peanut" because of its shape) has a modular body (three modules) which is 5.5 feet high, a rotor diameter of nine feet and a maximum takeoff weight of 440 lbs. The CL-227 is manufactured by Canadair, Inc. (a subsidiary of Bombardier, Inc.) of Montreal, Canada. A picture of the CL-227 during test operations is shown in Figure 39.

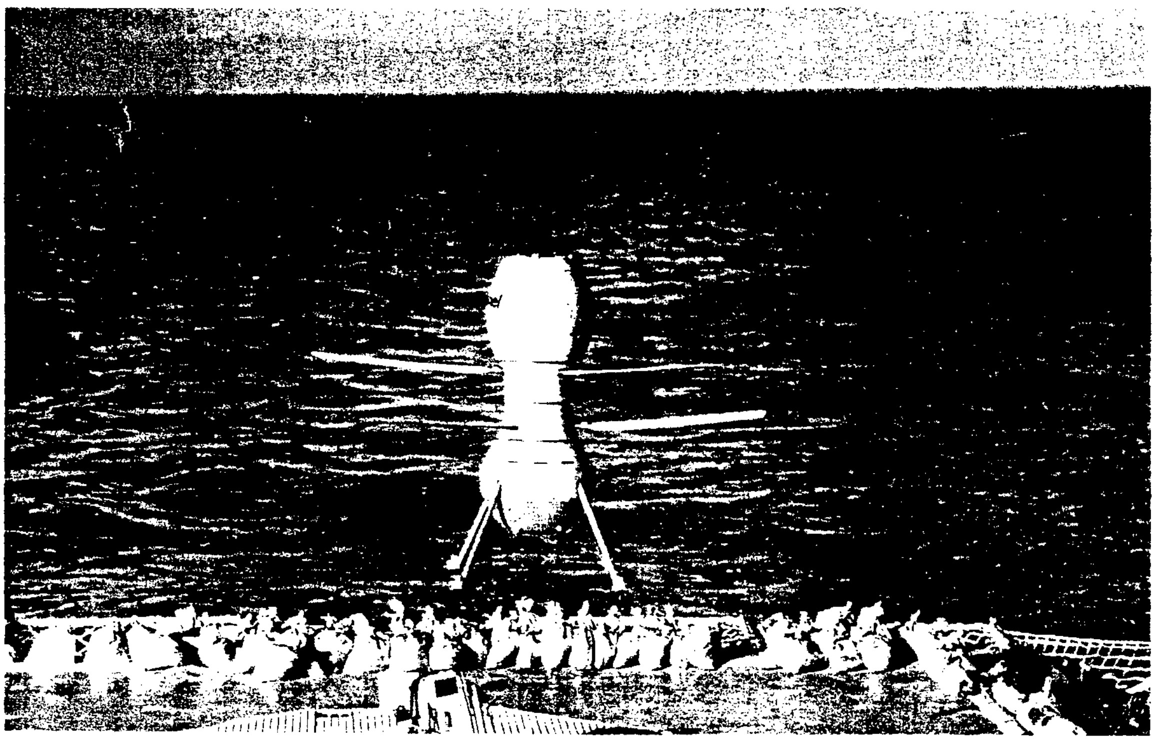


Figure 39 CL-227 Sentinel

The US and Canadian Governments have established a project agreement under the Defense Developmental Sharing Agreement for the development, test and evaluation (DT&E) of a CL-227 onboard a US naval combatant. This operation is funded through the Foreign Comparative Testing Program.

The MAVUS program provides the USN with the ability to evaluate the operational utility of UAV systems on small combatants; develop mission roles and tactics; and evaluate the ability of existing ship's crew to operate VTOL UAV systems as an adjunct to their existing duties. MAVUS was deployed on the USS DOYLE (FFG-39) with the Standing Naval Force Atlantic (STANAVFORLANT) in October 1991.

The members of the North Atlantic Treaty Organization (NATO) Project Group 35

(Canada, France, Germany, the Netherlands, Norway, the United Kingdom and the US) are all participating in the MAVUS project. Canada, the Netherlands, and the United Kingdom have their ships assigned to STANAVFORLANT with the capability to receive imagery from the MAVUS.

The MAVUS system includes: three Canadair CL-227 Sentinel VTOL air vehicles; day and night imaging, radio relay and EW payloads; an integrated MPCS with enhanced imagery exploitation capability; an integrated ship mounted dual antenna data link system; an independent launch and recovery system; and full logistics support. Contractor tests at Montreal and government tests at Patuxent River, MD were completed in September 1991. The system was then installed in the USS DOYLE (FFG-39). MAVUS completed operational demonstration in December 1991. A report of results will be available in June 1992.

B. FQM-151A POINTER

The FQM-151A Pointer is a very low cost, hand-launched, battery powered UAV. Both a black and white and color television camera are available as payloads. Pointer is backpackable in hard-shell containers attached to military issue field pack frames. The air vehicle container weighs 45 lbs. and the ground control unit (GCU) weighs 50 lbs. A new softpack for the air vehicle will weigh 23 lbs. and be air-droppable in parachute operations. The GCU controls the air vehicle, displays and records air vehicle video imagery, and records narrative provided by a ground observer.

The air vehicle is quickly assembled from six sections, has a nine foot wingspan and is six feet long. Launch weight is presently nine pounds with new replacement air vehicles a pound less. Recovery is executed by a deep-stall maneuver to a soft landing in a flat attitude. Pointer can be prepared for launch in less than five minutes by two personnel.

The air vehicle presently has a range of five km and a flight duration in excess of one hour. Optimal operating altitude for the air vehicle is typically 200 to 500 feet above ground level (AGL). One Pointer system normally includes four air vehicles and two GCUs. The mission of Pointer is reconnaissance and surveillance for lower-level ground combat units (e.g., infantry companies/battalions) within their local areas of responsibility. Only brief orientation training is required to qualify Pointer system operators. No unique educational background, formal school training, extensive military skills or uncommon physical skills are required.

Six Pointer systems were procured and delivered in 1990 for operational experimentation with units of the USA and USMC Logistics support and technical assistance were provided by Pointer's designer and manufacturer, Aerovironment of Simi Valley, CA.

Pointer was evaluated by the 2nd Infantry Division, 25th Infantry Division (Light), 7th Infantry Division (Light), 82nd Airborne Division, 8th Marine Regiment, 7th Marine Expeditionary Brigade and the DEA. Additionally, it was deployed in Operation Desert Storm with the 82nd Airborne division, 1st Marine Expeditionary Force (MEF) and 4th Marine Expeditionary Brigade. One system resides with the Army's 25th Infantry Division (Light) in Hawaii. Evaluation by additional USA and USMC elements is continuing through FY92/93.

C. CR VEHICLES AND FORWARD LOOKING INFRARED (FLIR) PAYLOADS

In April 1991 a RFP was released for technical demonstrations for 200 lb. class UAV and FLIR systems capable of being carried by a 200 lb. class UAV. Responses to the RFP were received in May 1991. Contracts were awarded in July 1991 to six contractors for 200 lb. class aerial vehicles and four contractors for lightweight FLIRs (see Figure 40). The air vehicle technical demonstrations are being held from February through July 1992 at Yuma Proving Grounds, Yuma AZ. The FLIR technical demonstrations were completed in February 1992 at Redstone Arsenal, AL.

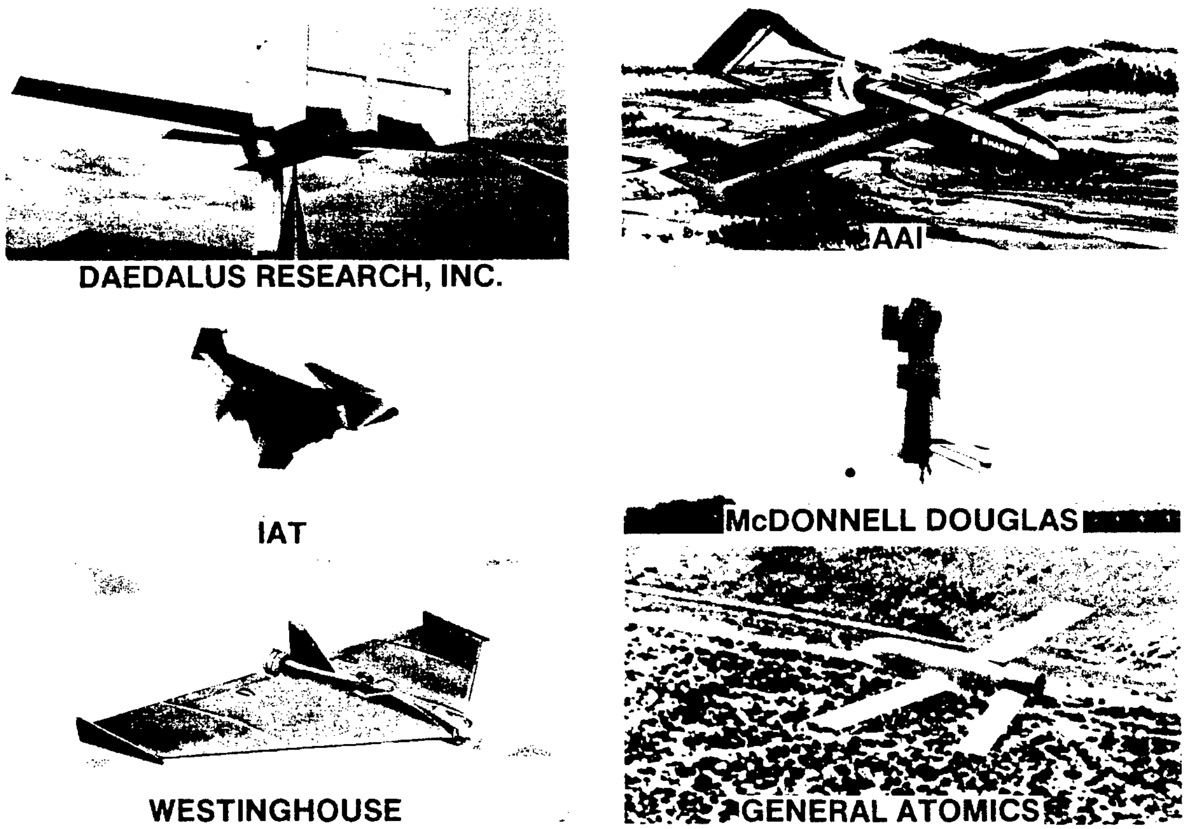


Figure 40 CR Air Vehicle Technology Demonstration Vehicles

- AAI Corporation, Hunt Valley, MD will demonstrate a conventional fixed wing, pusher prop design.

- Daedalus Research, Logan, UT will demonstrate a slaved tandem freewing vertical/short take off and landing (V/STOL) air vehicle.

- General Atomics, San Diego, CA will demonstrate a low wing, inverted tail, pusher prop design.

- International Aerospace Technologies, (IAT) Inc., Huntsville, AL will demonstrate a delta wing-canard, pusher prop configuration.

- McDonnell Douglas Missile Systems Company, St. Louis, MO will demonstrate a tailsitter design.

- Westinghouse Corporation, Baltimore, MD will demonstrate a delta wing, pusher prop configuration.

Of the four companies that received contracts to demonstrate lightweight FLIRs, one has been dropped from the technical demonstration program. The remaining three are as follows:

- Kollmorgen Corporation, Electro-Optical Division, Keene, NH demonstrated a micro-FLIR compact video rate optical scanner that operates in the 8 to 12 micron region.

- Rafael, Haifa, Israel demonstrated a parallel scanned mercury cadmium telluride detector array that operates in the 8 to 12 micron region.

- Rockwell International, Anaheim, CA demonstrated a photovoltaic mercury cadmium telluride staring focal plane array that operates in the 3 to 5 micron region.

D. TILT WING/ROTOR

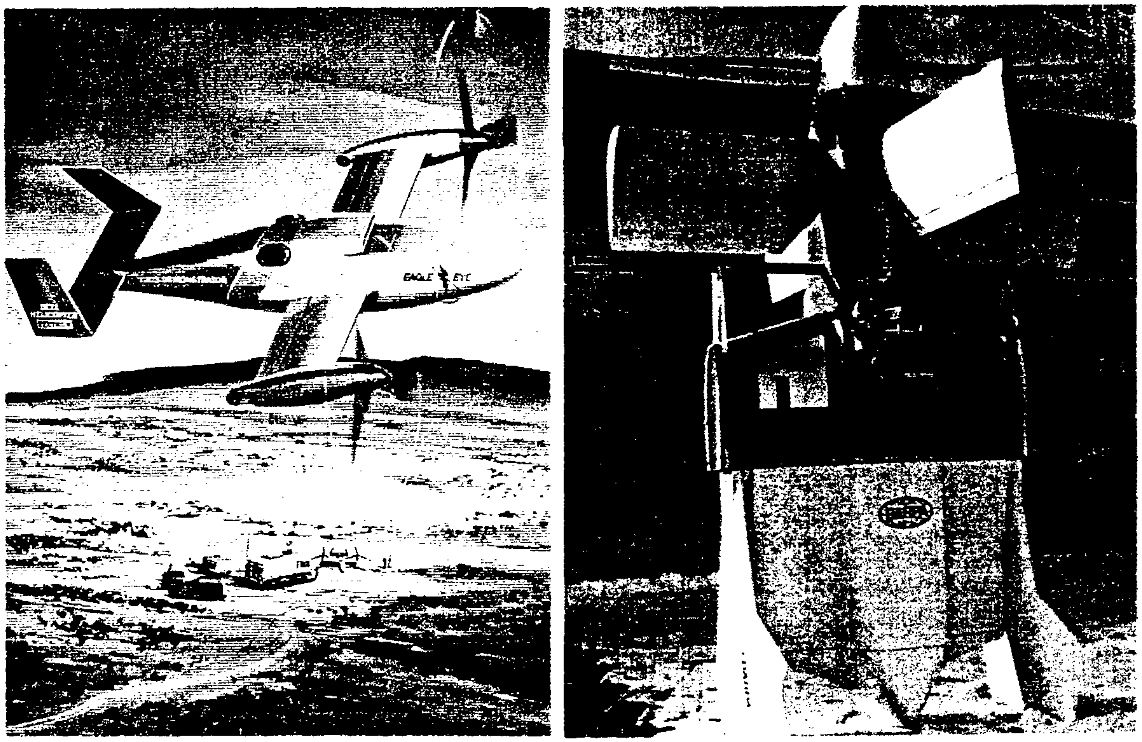
The objective of the demonstration program is to assess the state of the tilt wing/rotor UAV technology, provide data to assist in the technical requirements definition of a VTOL UAV program and accomplish technology risk reduction for the VTOL and other UAV programs.

Tilt Wing/Rotor is an attractive combination of rotary and fixed wing technologies. It provides VTOL and hover capability, along with low speed characteristics which are superior to fixed wing aircraft. In addition, its cruise and dash speed characteristics exceed that of rotary aircraft.

A two phase program is underway. The first phase is a four month effort, wherein the contractor will perform an engineering study and analysis of a tilt wing/rotor UAV in a maritime environment, and prepare applicable study reports dealing with the vehicle subsystem capabilities.

The second phase of the program is a contract option for a technology demonstration. In it the contractor will fabricate two vehicles for a two month, 40-flying hour demonstration program to be conducted at Yuma Proving Grounds, Yuma, AZ. The vehicle requirements to be demonstrated include VTOL, hover, 10,000 foot altitude, 150 knot dash speed, two hour endurance and launch and recovery in an area not greater than 36 by 36 feet.

A competitive source selection was completed in December 1991 and phase I contracts were awarded to Bell Helicopter Textron, Inc., Fort Worth, TX and SAIC, Arlington, VA on 24 December 1991 (see Figure 41). Award of phase II demonstrations is pending availability of FY92 funding.



Bell Helicopter SAIC

Figure 41 Tilt Wing/Rotor Demonstration Vehicles

E. BQM-147A EXDRONE

The EXDRONE BQM-147A consists of a delta wing air vehicle powered by a small 2-cycle gasoline engine. The air vehicle can carry a payload of up to 25 lbs., fly at a maximum speed of 100 miles per hour for up to 30 minutes, and can loiter for up to two and a half hours at altitudes up to 10,000 feet. Major components are the fuselage assembly, right and left wing assemblies, joining spar and vertical stabilizer assembly. The fuselage assembly includes the engine, payload bay, avionics equipment bay and field installable, canister packed safety parachute. Each wing contains a fuel cell and lithium battery, and consists of monocoque skin assemblies with a central wood wing rib and one piece blade spar passing through the fuselage and extending into each wing. Skin material consists of three millimeter foam core molded epoxy fiberglass.

The ground control subsystem consists of radio control equipment, a data display, and a monitor that shows the video camera image. Initial takeoff and climb is controlled by a pulse code modulation controller. After launch, control and monitoring of the

EXDRONE can be accomplished using the ground control equipment.

The ground support subsystem includes support equipment for autopilot programming, payload testing, fueling, and launching of the air vehicle. Launch is accomplished by bungee catapult of the EXDRONE on a three-wheeled dolly and landing is accomplished on a four point skid system. The air vehicle can also be recovered using a canister packed safety parachute.

The EXDRONE is launched from a prepared surface by two crew members. Takeoff, climb out and turn to the desired heading is accomplished by radio control. After achieving the desired heading, the EXDRONE is given a radio control command to switch control to the autopilot. The autopilot controls the EXDRONE for the duration of the mission, although ground control can be reacquired if desired. The EXDRONE operating area is normally within 50 km of the FLOT. The onboard video camera will provide live color television monitoring of enemy activity within the operating area for a preset time and the EXDRONE will then be recovered.

Because the EXDRONE is expendable, no maintenance above organizational level is required. A typical operational scenario is depicted in Figure 42.

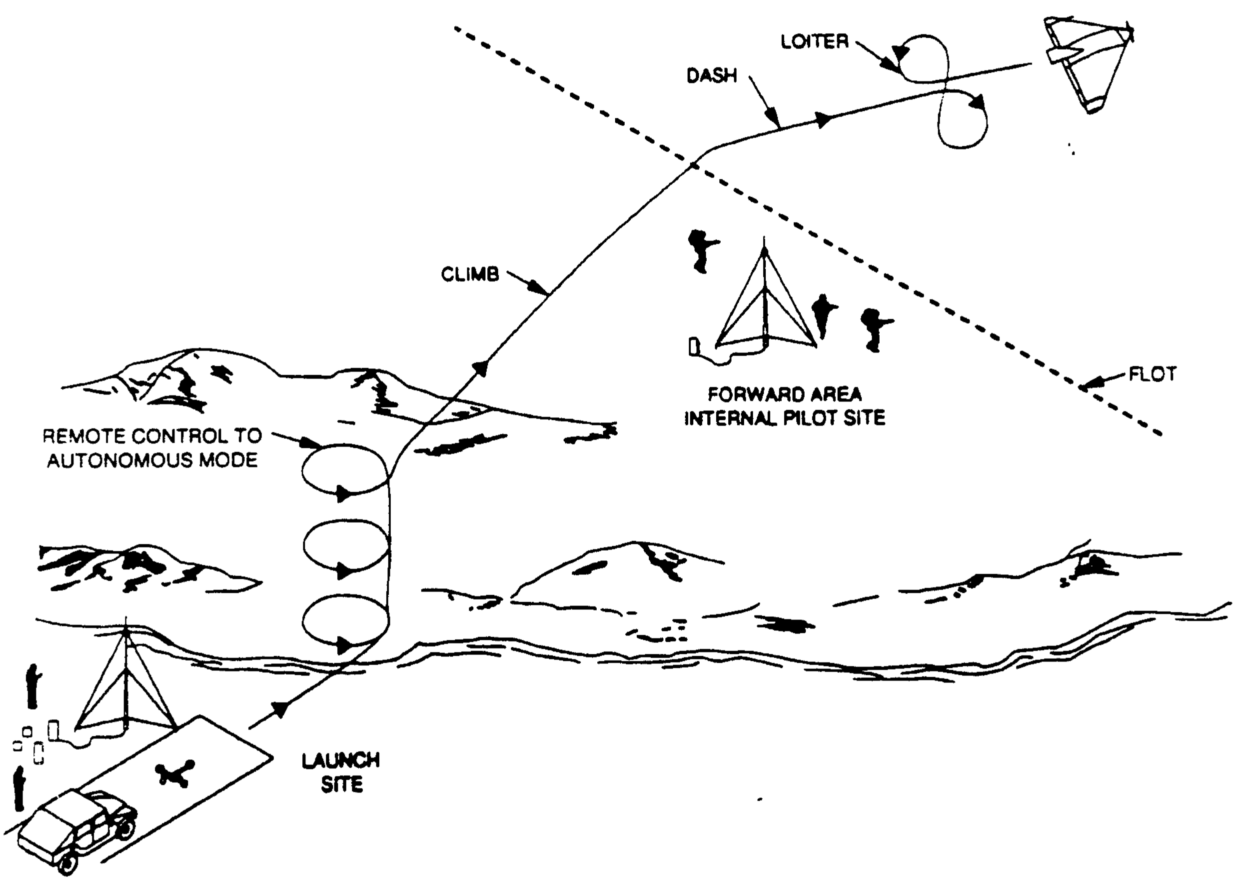


Figure 42 Typical EXDRONE Operation

The UAV JPO awarded a cost plus incentive fee contract to BAI Aerosystems, Inc., Easton, MD in November 1991 for the production of 110 EXDRONEs. These vehicles will be delivered over a seven month period. Training for the units participating in the operational demonstration is scheduled to begin during April-May 1992.

Additionally, the USMC has an existing requirement to provide tactical ECM support to the MAGTF Commander. The required operational capability (ROC) for the EXDRONE Communication Jammer defines a requirement for a small, low cost, expendable UAV capable of performing communication jamming operations on the enemies' side of the FLOT. The EXDRONE Communications jammer complements ground based ECM systems in the MAGTF.

The EXDRONE Communication Jammer program is a USMC unique program. System development has been ongoing since 1985. The program successfully completed developmental and operational testing at the White Sands Missile Range, NM in September 1987. Establishment of the UAV JPO in 1988 suspended USMC efforts until an appropriate UAV could be procured.

During 1990 and 1991 the USMC continued to develop a communication jammer in the tactical HF and VHF communication range. It also began the integration of the jammer into the UAV JPO BQM-147A EXDRONE air vehicle. During this developmental period GPS was incorporated into the system architecture to achieve navigational and loiter requirements. Electromagnetic interference (EMI) testing was also conducted and radio frequency shielding applied to aircraft avionics systems. Developmental flight testing was conducted in August, September and November 1991 with 42 flights and 27.5 flight hours successfully accomplished. Procurement based on a government technical data package is planned upon completion of operational test and production approval. However, operational test and production are not funded at present.

F. DRUG ENFORCEMENT ADMINISTRATION (DEA) PROGRAM

The USMC UAV program office is working with the DEA to procure a VLC UAV system. The goal of the project is to validate the concept of using small VLC UAVs for surveillance in counternarcotics operations. The evaluation will be conducted during the fourth quarter of FY92 and the first quarter of FY93.

UAV demonstration schedules are shown in Figure 1, page 5.

VIII ADVANCED TECHNOLOGY AND PAYLOADS SUMMARY

In 1989 the UAV JPO began a coordinated effort with DARPA, other agencies, defense laboratories, and the Services to identify technology areas that were pertinent to the development of UAVs. This has resulted in an Advanced Technology Plan which will be signed by DARPA and the UAV JPO this year. The plan enumerates ten separate subsystem areas where technological development will enhance UAVs in the future (See Figure 43 below). Plan details are provided in Appendix C, while Appendix D provides an assessment of payload technologies.

SUBSYSTEM	GENERATION I (0-4 years in future)	GENERATION II (5-9 years in future)	GENERATION III (10-15 years in future)
AIR VEHICLE & AIRFRAME	Off-the-shelf with signature reductions	LO/Stealth; Conformal antennas; V/STOL	Smart skins
ENGINE	Initial heavy fuel	Scalable, heavy fuel	Lightweight, high power density
LAUNCH & RECOVERY	Minimum-length launcher; Autonomous landing	V/STOL; Low dynamic controlled air vehicles	Electromagnetic launcher
AVIONICS	Modular Integrated Avionics Group (MIAG)	Laser ring buss; Hardened microelectronics; Fiber optic gyros	Fly-by-light; Superconducting INS
PAYLOADS & SENSORS	MTI/SAR/ISAR radars; ELINT/COMINT;	Multi-spectral/multi-mode Bi/Multi/static radar; MMW radar; Gen II EO/IR; MASINT; LIDAR	Distributed aperture optics; Non-cooperative target recognition; UWB radar
ELECTRONIC WARFARE	Lightweight comm/radar jammers; Towed decoys	MMW/Laser/EO detectors; RF/EO active expendables	High power jamming; Deceptive comm jam; Full spectrum jammers
DATA LINKS	Low cost, programmable format; Data compression	MMW data link; Laser communications	Radar/data link Integration; Universal translator; UWB data link
MAN-MACHINE INTERFACE MPCS	Commercial workstation; ISPS variant; Computer controlled flight	"UAV Associate"; Wide band recording and mass storage; Automatic target recognition	"Virtual Reality"; Robotic/autonomous operations; Automated analysis
HUMAN ENGINEERING	Embedded training; IMIS/CALS reconfigurable crew station	Courseware authoring tools; Automated maintenance aids	Intelligent tutoring systems
COMPUTATIONAL SUBSYSTEMS	Advanced microprocessors	Transputers; Neural nets; Parallel processors	Photonics; Neurocomputing

LEGEND

CALS - Computer-aided Acquisition Logistics Support
COMINT - Communications Intelligence
ELINT - Electronic Intelligence
EO - Electro-Optical
IMIS - Intelligence Management Information System
INS - Inertial Navigation System
IR - Infrared
ISAR - Inverse Synethetic Aperture Radar
ISPS - Integrated Strike Planning System
LIDAR - Light Detection and Ranging
LO - Low Observables
MASINT - Measurement and Signatures Intelligence
MET - Meteorological
MMW - Millimeter Wave
NBC - Nuclear, Biological and Chemical
RF - Radio Frequency
SAR - Synthetic Aperture Radar
UWB - Ultra Wide Ban
V/STOL - Vertical/Short Takeoff and Landing

Figure 43 UAV Technology Roadmap

IX ANALYSIS AND SIMULATION

The UAV JPO has a comprehensive analysis and simulation plan dedicated to ensuring that characteristics of the UAV family cost effectively meet Service requirements. The plan includes survivability and vulnerability analysis, COEA and computer simulations of operational requirements and concepts.

The UAV JPO has prepared a UAV survivability and vulnerability plan that provides a standardized method for analyzing all UAV systems. The plan addresses threat analysis and air vehicle, payload sensor, data link, and GCS susceptibility and vulnerability. In addition to providing stand alone information to decision makers on UAV system survivability, the analyses are also a major contributor to the COEA.

The COEA process was begun in 1989 at the direction of the EXCOM. The initial studies, termed the Phase 1 analyses, addressed the broad issue of whether UAVs belong in the "Defense Portfolio". The Phase 1 efforts began with a survey identifying high-payoff missions which might be performed by UAVs. Each mission was studied separately to determine the cost effectiveness of using UAVs. The results of these analyses were collected and one common theme emerged-UAVs are a cost effective alternative to manned aircraft and other conventional assets for information collection. The second phase of the UAV COEA process will verify if the UAV family is properly constituted to perform the missions envisioned. This study will be finished during the fourth quarter of FY92.

The requirements delineated in DODI 5000.2 are being addressed for new COEA work. A COEA will be performed on each UAV system prior to major milestones. Before beginning each COEA, a study director will be assigned and an analyses plan submitted to ASN(RD&A) for approval. In May 1992 the present COEA Steering Group will be disestablished and the USN, as Executive Service, will have full management responsibility for UAV COEAs. Where possible the studies will use measures of effectiveness that are directly related to TEMP parameters.

To supplement these analyses, the UAV JPO maintains a computer simulation capability which is networked to other geographical sites around the country. This Simulation Network (SIMNET) was developed by DARPA in the early 1980's and is presently operated by the USA as a system design and training tool. The UAV JPO is considering using SIMNET in a new project sponsored and funded by DARPA called Synthetic Environment for Requirements and Concepts Evaluation Simulation (SERCES). The project's goal is to create a simulation network capable of analyzing the requirements and CONOPS of a system before an investment in development hardware is made. Thus both acquisition cost and time should be reduced. The project will link simulation facilities at the Naval Ocean Systems Center (NOSC), San Diego, CA, with the JDF. Using a variety of existing simulation and wargaming capabilities, UAVs will be studied. Initial efforts will focus on validating the information developed to date in the VTOL ORD development process. Wargame simulations at NOSC, creating realistic operational scenarios, will run in conjunction with high fidelity UAV engineering models at the JDF. The use of this simulation can quickly be expanded to all the other UAV programs.

X INTERNATIONAL

The UAV Joint International Programs Directorate became operational 1 October 1991. It is the UAV JPO focal point for all foreign or international UAV programs. This includes participation in the NATO working groups; coordination of foreign military sales (FMS); export licenses; international exchange programs; formulation and coordination of memorandum of understandings (MOUs); MOAs; data exchange agreements (DEAs) and the promulgation of policy. Additionally, it serves as the primary point of contact for foreign officials visiting the UAV JPO and ensures coordination and approval with the Defense Intelligence Agency (DIA). Responsibilities include:

- **Production & Logistics**
  - Coproduction
  - FMS/Direct Sales/Offsets
  - Munitions Export Licenses
  - Logistics (Training/Initial Spares)

- **Documentation & Formal Agreements**
  - MOUs and MOAs
  - Cooperative Opportunities
  - Acquisition Plans

- **Policy**
  - Technology Transfer
  - Foreign Disclosure

- **Testing & Development**
  - Codevelopment
  - Foreign Comparative Testing (FCT)

- **Information Exchange**
  - NATO Working Groups
  - Foreign Visitors
  - Data Exchange Agreements/Information Exchange Programs
  - International UAV Data Bases

The objectives for FY92 include laying the ground work and infrastructure for foreign sales and possible cooperative opportunities.

XI TEST AND EVALUATION (T&E)

OVERVIEW

Joint UAV testing consists of both developmental test and evaluation (DT&E) and OT&E. It utilizes personnel, test sites, and test facilities of all the Services. DT&E and OT&E may be conducted both sequentially and in parallel in order to minimize costs, exploit special test capabilities and expedite test schedules. The Naval Air Warfare Center Weapon Division, Pt. Mugu, CA, (NAVAIRWARCENWPNDIV PT MUGU) has been designated as the lead field activity for DT&E. A Joint Test Coordinator at NAVAIRWARCENWPNDIV PT MUGU coordinates DT&E and supports OT&E as requested. The USN Operational Test and Evaluation Force is the lead operational test agency for OT&E.

DEVELOPMENTAL TESTING

Government test sites possessing sufficient restricted airspace, ground space and sea space to conduct UAV testing are limited in number and are generally located in the western portion of the US. Most of these test sites have workloads that normally require the prioritization of test projects. However, a review of UAV suitable test sites indicates that sufficient test capabilities presently exist to support all DT&E, albeit at different test sites. Thus, little new investment in test facilities/capabilities is needed. One test capability that does not now exist at any Government test site, and will be required for and funded by the VTOL UAV program, is a land-based ship motion simulator (SMS). The SMS will be a landing platform with multiple degrees of freedom. The purpose of the SMS is to replicate a large number of complex ship motions representative of several classes of ships in various sea states. A functioning SMS is required by FY97 to support VTOL UAV DT&E. Individual program TEMPs will indicate other resource shortfalls as they are identified.

OPERATIONAL TESTING

While the successful completion of UAV DT&E is relatively straightforward, OT&E presents a more difficult challenge. First, experienced military personnel serving in operational UAV units are required to support OT&E. Because the number of operational UAV units is presently very small and heavily committed to contingency operations and training, the availability of experienced UAV personnel is less than desired. The UAV JPO will work closely with the Services to obtain the minimum number of experienced UAV personnel to accomplish operational testing.

Secondly, operational test realism requires that OT&E be conducted at test sites possessing natural environments representative of UAV deployment settings. Operational realism also requires the participation of various interfacing and supporting units and the presence of complex target arrays. Thus, operational test realism for UAV systems is substantially driven by the availability of experienced personnel, representative test sites and resources.

Thirdly, field level logistics support is required so that it may also be tested in OT&E. Generally, logistics support for a UAV system is not mature during DT&E and OT&E. However, logistic support must be sufficiently developed to allow operational personnel to perform organizational level maintenance during OT&E.

SURVIVABILITY TESTING

The predicted survivability of a UAV system in a combat environment is a critical parameter which must be quantified in a cost effective manner to a reasonable level of confidence. The use of destructive field tests involving a panoply of air defense weapons integrated into a realistic combat scenario and firing live ammunition is extremely expensive. However, using non-destructive field test results to determine susceptibility and a small number of controlled destructive field tests to determine vulnerability, survivability can be determined to a reasonable level of confidence using computer simulations incorporating force-on-force models. Operational training exercises also hold potential for determining UAV survivability at reasonable cost.

To accurately predict UAV system survivability in an operational environment, representative user personnel must be employed to obtain tactical expertise and specific training. Such personnel will perform mission planning to determine the best solution comprising both mission accomplishment and system survivability. To assure that only certified computer models are employed in the analysis of operational UAV survivability, the services of the Survivability Information and Analysis Center (SURVIAC), a DoD technical center with acknowledged expertise in aircraft survivability, will be used.

TEST SCHEDULES

Scheduled DT&E and OT&E periods for the CR, SR, and MR UAV systems are contained in Figures 20, 23 and 37 respectively.

XII INTEGRATED LOGISTICS SUPPORT (ILS) AND HUMAN SYSTEMS INTEGRATION (HSI)

INTEGRATED LOGISTICS SUPPORT (ILS)

The consolidation of the Services' UAV acquisition activities within the UAV JPO offers a unique opportunity to implement initiatives for improving UAV ILS, human systems integration and both common-core and Service unique training. The research, development, test and evaluation (RDT&E) and procurement funds come through the UAV JPO. With the Services and Allies providing their own operational and maintenance (O&M) funding, an ILS strategy which effectively produces economies of scale, yields high readiness levels and alleviates waste caused by individual Service logistics planning, implementation and provisioning is a major objective. The end users will be the main focus for joint logistics initiatives.

To accomplish these initiatives involves:

- Centralizing the management and implementation of UAV logistics support.

- Improving transportability of training across Service unique barriers by using common development standards.

- Producing computer-based training (CBT) materials which are effective on Service unique operating systems (both hardware and software).

- Developing a depot maintenance strategy which can address the most economical methods of support for all UAV fielded systems.

- Evaluating all human considerations for the O&M by sailors, soldiers, airmen and marines.

- Requiring greater system I&C.

The UAV JPO will be an advocate for initiatives to enhance the logistics support for all UAV systems and to encourage International logistics cooperation. One such initiative is the establishment of a UAV JL-COE. This initiative, approved by the Joint Logistics Commanders in September 1991, provides the structure to allow an existing logistics support activity to provide negotiated levels of support to each requiring UAV program office. The UAV JL-COE is located within the Army Missile Command (MICOM) at Redstone Arsenal, AL, and has been created by a MOU between the UAV JPO and the Integrated Missile Maintenance Center (IMMC). This activity will become the central focus for future UAV logistics support and the center for initiatives to enhance family I&C within the logistics support community. Efforts to improve UAV logistics support, by requiring common/existing support equipment, minimum new training requirements/equipment, and maximum use of existing Service hardware, will be a major tasking of the UAV JL-COE. Improvements to existing support procedures will be encouraged and incorporated when they enhance system availability and operational readiness or reduce life cycle costs. The JL-COE has the opportunity to introduce new and innovative methods for improving joint systems supportability.

The Joint Logistics Assessment (JLA) is another initiative started within the UAV programs. The JLA will provide a consolidated joint evaluation of the logistics health of

each UAV program prior to each milestone decision. This new initiative will begin with a test case that has been developed by a working group consisting of representatives from all Services. Each Service has agreed to participate in this initial evaluation and to accept the results of the formal evaluation without requiring a Service unique duplicate process. The working group has prepared joint logistics assessment checklists to guide the Logistics Assessment Team (composed of logistics evaluators from all services) in their joint evaluation of the test case program which will be the SR UAV production decision. This joint evaluation process (supported by an interservice MOA) may be used by each Service's logistics community to determine their input to the logistics health of this UAV program. It is anticipated that this test case will result in a formal process for the future evaluation of all UAV joint programs. The process may become a valid method to evaluate the logistics health of any joint program as well as a basis for Service unique programs.

The Joint Logistics Management Information System (JLMIS) is a UAV JPO initiative to provide the UAV program offices with access to UAV related logistics data. The JLMIS will reflect DoD Computer-aided Acquisition Logistics Support (CALS) requirements. This system will provide the capability to connect UAV logistics activities with UAV related data bases (both [Contractor Integrated Technical Information Service (CITIS)] and [Government Integrated Technical Information Service (GITIS)] for rapid and integrated analyses to enhance logistics support and assessments. System planning will allow this capability to support the program offices with information required to help determine system specifications, readiness levels and supportability requirements. A phased implementation allows the system to grow with the increase in UAV systems and funding. There will be maximum use of existing software programs within the Services' logistics community. Modified/standardized software programs will be required whenever they can meet the joint Services' logistics requirements. This capability will be available to all UAV activities to encourage commonality within the joint support arena.

The UAV Joint Logistics Steering Panel, which consists of the Joint Logistics Directorate and all UAV program ILS managers (lead and participating), will focus on identifying and implementing the most cost effective UAV logistics programs. Expert points of contact (POCs) will be identified by the Joint Logistics Directorate to provide the steering panel with the essential expertise of their logistics element specialities. The POCs , drawing from the SR UAV baseline system experience, will identify and monitor essential requirements/constraints for inclusion in the other UAV programs.

The JTC will assist in providing expertise to develop, implement and maintain the JLMIS. The JTC will also assist in providing the expertise to develop and maintain the repository of technical and logistics data essential to proper logistics support of the UAV family. This forum will allow the cross flow of ideas and tentative solutions, which may generate future initiatives to create enhanced processes to support the UAV family. The UAV Joint Logistics Steering Panel will pursue logistics initiatives which ensure improved/sufficient support for all UAV systems. These include:

- Monitoring the development of field level logistics support and advising the cognizant ILS manager of systems lessons learned, opportunities for commonality and interoperability and also assuring that participating Services' requirements are met. The steering panel will be established, members identified and initial meetings held in FY92 to review current programs.

- Minimizing organic and intermediate level test equipment. Existing support equipment to be used should be identified in order to reduce proliferation of test equipment and aid in support equipment commonality. The panel, through the JL-COE, will ensure this survey of support equipment is performed on an on-going basis, beginning in FY92.

- Establishing logistics constraints for maximum weight and volume of organizational level support equipment. This should provide the most efficient and effective support with the minimum amount of personnel and equipment. The panel will ensure that the application of constraints is consistent with applicable standards and is uniform across the UAV family. The monitoring will be accomplished by the actions of the JL-COE and appropriate POCs. Starting in FY92, these actions will begin by review of acquisition documentation.

- The panel will utilize the JLMIS to ensure commonality of hardware and support resources among the UAV variants, and interoperability with existing equipment. Life cycle costing during the initial stages of development will be monitored by the panel to enable them to provide inputs to each program to minimize O&M funding requirements.

The uniqueness of the UAV JPO structure allows for the introduction of new and creative concepts. Careful and complete coordination of future UAV logistics processes and procedures should provide further initiatives to enhance the Services' support to their fielded systems.

HUMAN SYSTEMS INTEGRATION (HSI)

In support of documentation requirements of DoD Directive 5000.1 and DoD Instruction 5000.2, each UAV program will prepare both HSI and Training Development Plans. Both plans will address trade-offs between cost and performance and, in addition, will address HSI impacts upon design and schedule. UAV programs will follow USN and UAV JPO policy and guidance for development of these plans. Each UAV program will have an individual identified as responsible for HSI.

The steering panel will monitor these plans to ensure they are consistent with joint UAV family HSI objectives. These objectives will be developed beginning in FY92 and will assure consistent integration of human system factors by the individual UAV programs.

Manpower and Personnel - As is required for ACAT 1 programs, each UAV program will prepare a manpower estimate report, which will be submitted at acquisition Milestones II and III. Manpower requirements will reflect estimates prepared by each participating Service and submitted to the cognizant program office. In general, manpower requirements will be minimized as much as possible.

Training and Training Devices - Training for UAVs will reflect a minimizing of personnel and training. Where possible, training generic to one or more programs will be institutionalized as "common-core" training. Common-core training will be conducted at one or more training sites. Service unique training will be the responsibility of each participating Service and may or may not be held at a common-core training site. To date, one common-core training site has been identified: Ft. Huachuca, AZ. Ft. Huachuca will support both the SR UAV (operational in 1995) and CR UAV. The USA has been designated as the UAV JPO training agent for the SR and CR UAVs.

Training for the MR UAV will be at sites identified in the MR UAV Training Plan. Where possible, formal training will be minimized and alternative approaches [including on-site computer-based training (CBT) and embedded training] will be investigated.

XIII UAVs IN DESERT STORM

While a knowledge of the disposition of enemy forces has always been fundamental to successful combat operations, today's combat commander places a high premium on reconnaissance systems which provide real time and/or near real time imagery intelligence. This information is valuable because it provides the operational commander a significant warfighting advantage--the ability to formulate effective battle plans, while responding almost simultaneously to enemy actions on the battlefield.

In Operation Desert Storm US combat commanders operated three types of UAVs that provided real-time imagery intelligence. The success of UAVs in Desert Storm affirmed the military Services commitment to integrate UAV systems into their force structures for a number of missions.

One broad conclusion drawn from Operation Desert Storm is that although the concept of a family of UAVs is valid, varying requirements call for a degree of specialization among UAV systems based on mission, Service, and echelon of command supported. Ultimately, only the air vehicle portion of a UAV system needs to possess a very high degree of specialization, primarily due to aerodynamic performance requirements. Other elements of UAV systems can be common among members of the family of UAVs.

SR CATEGORY

Six Pioneer UAV systems participated in Operation Desert Storm - three with the 1st MEF, two with the USN battleships USS MISSOURI and USS WISCONSIN, and one with the USA VII Corps. The Pioneer system provided near real time reconnaissance, surveillance, target acquisition and spotting, and BDA during both day and night operations. Figure 44 shows crewmen readying a Pioneer for takeoff from an airfield in Saudi Arabia.

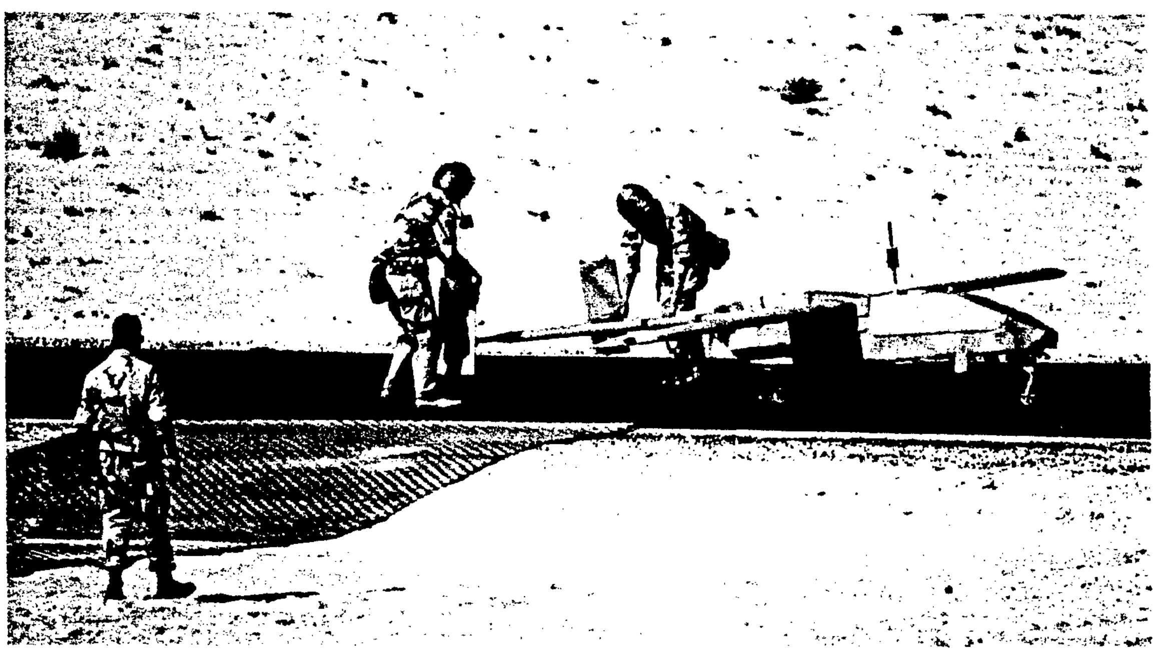


Figure 44 Readying Pioneer for Takeoff in Saudi Arabia

Each Pioneer system supported multiple units and performed different reconnaissance missions on each flight. Significantly, airborne Pioneers were often tasked to verify radar contacts generated by the Joint Surveillance and Target Attack Radar System (JSTARS) aircraft. JSTARS and Pioneer coordinated operations worked very well; JSTARS served as a wide-area alerting sensor for high priority mobile targets and Pioneer acted as the confirming sensor.

Pioneer also proved to be survivable. While manned aircraft tended to fly mostly at medium altitudes for enhanced survivability, Pioneer flew all missions below 5,000 feet AGL and within the envelope of optically directed guns and IR missiles. In 302 sorties and 1050 flight hours, only one Pioneer was lost as a result of enemy actions.

Airspace integration and command and control of Pioneer operations was superb. Each Service chose to handle flight coordination of Pioneer with manned aircraft differently, but in each case the result was highly satisfactory. The concerns raised prior to Desert Storm as to the "mixability" of UAVs and manned aircraft were shown to be solvable.

Pioneer system availability was maintained at a high level throughout combat operations - but only through the extraordinary efforts of the UAV JPO, AAI Inc. and operational units. Because Pioneer is an interim SR system, it is logistically supported entirely through the Pioneer contractor, AAI Corporation, Hunt Valley, MD. To support the six Pioneer systems deployed in Desert Storm, the UAV JPO established a Forward Logistics Support Detachment at Bahrain using both US Government and AAI contractor personnel. This detachment provided highly responsive supply and depot level maintenance support. This ensured a high level of system availability.

Pioneer does have some limitations, which were clearly demonstrated in Desert Storm. When operated as a Corps level asset with the USA VII Corps, Pioneer did not have the range and endurance required for all ground operations. Seventh Corps clearly needed a UAV system with a radius of action of about 300 km using an airborne data relay plus a time on station in excess of four hours at maximum range. Pioneer range was generally satisfactory for the USN and USMC, but additional endurance would have been welcomed. At night, mission endurance was further reduced in some cases by an inadequate FLIR cooling system. Additionally, lack of a GPS navigation capability prevented Pioneer from providing precise information for the targeting of weapons.

Pioneer's launch and recovery characteristics were also a major limitation. Both the USA and USMC had to construct UAV airfields on short notice to support the ground force scheme of maneuver. This required the diversion of critical engineer resources from combat operations. Aboard ship use of a net recovery system was manpower intensive, can cause air vehicle damage, and restricts the use of deck space on most ships.

Pioneer's use of 100 octane aviation gas was a logistic limitation because it is not in the US military supply system, and could only be obtained in Bahrain. The next closest source was Greece. Also, the lack of a laser target designator capability for Pioneer precluded use in laser spotting of targets. With a great number of laser guided munitions present on the battlefield, a laser target designator for Pioneer could have assisted in the attack of high value, mobile targets.

Although only one Pioneer air vehicle was downed by Iraqi air defenses, 12 others were destroyed in operational accidents. Material/subsystem failures, operator error and cosite EMI between Pioneer systems and other high power microwave emissions undoubtedly accounted for the majority of losses.

Finally, imagery dissemination from the Pioneer GCS to using units was not satisfactory. The Pioneer remote receiving system units were deficient in both operating range and data dissemination capability. USMC Pioneer units did construct a nonsecure, ground microwave system to the 1st MEF Command Post some 15 km away, using commercial equipment borrowed from the USAF. This link was judged highly effective in keeping the 1st MEF Headquarters informed on a real time basis.

CR CATEGORY

Two types of VLC UAV systems in the CR category were deployed in Desert Storm. Five FQM-151A Pointer systems were provided to USA and USMC units and one BQM-147A EXDRONE system was provided to the USMC.

Operational experience with these systems has provided some valuable insights on the required characteristics of a CR system. These are listed as follows:

a. Mission: Perform reconnaissance and target acquisition using high resolution imagery sufficient to distinguish friendly from enemy forces.

b. Radius of Action: Operate in a 10-60 km range band.

c. Navigation: GPS type accuracy at all ranges sufficient to support rapid engagement by fire support elements without the need for round by round adjustment.

d. Launch and Recovery: Perform in unimproved, clear areas in high wind conditions.

e. Construction: Ruggedized for a harsh field environment.

f. Responsiveness: Immediately available to maneuver battalion commanders.

g. Operator Skill/ Training: Low degree with emphasis on on-the-job-training to acquire necessary proficiency.

h. Transport: Entire system carried in a single HMMWV; system man portable when disassembled.

MR CATEGORY

A high speed UAV in the MR category was not used in Desert Storm. But if one were it could have acted as a force multiplier by augmenting/complementing the heavily-tasked reconnaissance aircraft. Collection of pre- and post-strike imagery at low altitudes using a MR UAV system with a high resolution, EO sensor, could have provided timely targeting data as compared to film-based systems. A MR UAV system will need the following characteristics to satisfy user needs:

a. High resolution imagery.

b. Near real time data collection.

c. Day/night/adverse weather capable.

d. Sufficient range to cover targets of interest.

ENDURANCE CATEGORY

No Endurance category UAV was used in Desert Storm. However, there were numerous generic missions during Desert Storm which could have been performed by a UAV in the Endurance category. Examples include EW, communications/data relay, and meteorological/oil fire surveillance. However, the mission of theater missile early warning defense appears especially suited to an Endurance UAV. A long endurance platform with appropriate sensors could have detected enemy mobile missile launchers prior to missile launch and could have tracked expended launchers after missile launch. One Pioneer unit actually tracked an Iraqi Free Rocket Over Ground (FROG-7) missile launcher from its hiding place in a fire station in Kuwait all the way down to the Saudi border where the FROG-7 set up and fired into Saudi Arabia.

SUMMARY

The tremendous success of UAV systems in Operation Desert Storm sends a strong message regarding the utility of UAV systems in combat. In an era of budget constraints, doing more with less is mandatory. UAVs have the capability to perform multiple functions and significantly enhance battle management systems, and are excellent force multipliers due to their combat utility, versatility and cost effectiveness. These Desert Storm lessons learned are being applied to their respective UAV systems. The lessons have helped to reaffirm the course and direction that have been taken with the SR, CR, MR, and VTOL UAV programs.

XIV RESOURCES

DoD fiscal resources sponsor for UAV systems is OSD Tactical Warfare Programs (TWP). Funds execution is accomplished by the UAV JPO. Nonlethal RDT&E and procurement UAV activities are programmed and budgeted in Program Element (PE) 0305141D.

A. RESEARCH, DEVELOPMENT, TEST AND EVALUATION (RDT&E)

Most RDT&E is programmed and budgeted in OSD PE 0305141D. These funds support systems, subsystems, component and interoperability/commonality RDT&E. Additional RDT&E is programmed and budgeted in related Service and agency PEs following coordination with UAV JPO. For example, systems evaluated in the FCT program are funded in PE 0605130D.

B. PROCUREMENT

Procurement is programmed and budgeted in OSD PE 0305141D.

C. OPERATIONS AND MAINTENANCE (O&M)

O&M is programmed and budgeted by the Services in their program element.

D. MILITARY PERSONNEL

Military personnel end strengths and pay are individually programmed and budgeted by the Services.

E. MILITARY CONSTRUCTION (MILCON)

Military construction (MILCON) programming for UAVs is the responsibility of the UAV JPO. Service unique construction is the responsibility of the requiring Service.

F. FUNDING

The OSD PE 0305141D budget is:

	FY92	FY93 Amended Budget Submit	Future Year Defense Plan (FYDP) (FY94 - FY99)
RDT&E	$ 66.9M	$129.1M	$514.6M
PROCUREMENT	$138.4M	$148.9M	$1650.4M

APPENDIX A:
GLOSSARY OF TERMS

Unmanned Aerial Vehicle (UAV) - A powered aerial vehicle that does not carry a human operator, uses aerodynamic forces to provide vehicle lift, can fly autonomously or be piloted remotely, can be expendable or recoverable, and can carry a lethal or non-lethal payload. Ballistic or semi-ballistic vehicles and artillery projectiles are not considered UAVs.

Lethal UAV - A UAV, normally autonomous and expendable, that carries a payload used to attack, damage and/or destroy enemy targets.

Nonlethal UAV - A UAV that does not carry a payload for physical damage and/or destruction of enemy targets. A nonlethal UAV carries payloads for missions such as RSTA; target spotting; command and control; meteorological data collection; NBC detection; special operations support; communications relay; and electronic disruption and deception. In the context of this document the term "UAV" is equivalent to the term "nonlethal UAV."

Remotely Piloted Vehicle (RPV) - A nonautonomous UAV; that is, one that is controlled through a data link by human operator.

Conventional Standoff Weapon - An unmanned, surface attack, powered or unpowered ballistic missile, semi-ballistic missile, cruise missile, or UAV having an explosive or otherwise lethal non-nuclear warhead and having an effective operational range exceeding five nautical miles from its lowest operational launch altitude. USA deep fire systems are considered standoff weapons, but USA artillery and artillery-like close fire systems are not.

The following additional terms used throughout this document pertain to qualities or characteristics of UAVs:

Category of UAV Requirements - Close, Short, Medium and Endurance.

Commonality - The ability to identify and capitalize on opportunities for savings and efficiencies through the use of common systems, subsystems and components within the UAV family and with other DoD programs.

Family - The set of UAV systems that maximizes I&C.

Interface - The physical, electrical, environmental, and functional hardware and software requirements, characteristics and constraints that exist at a common boundary between two systems.

Interoperability - The ability of systems, units, or forces to provide services to and accept services from other systems, units, or forces and to use the services so exchanged to enable them to operate effectively together. Interoperability is an operational requirement while commonality is a life cycle cost decision.

Subsystems - The major elements of a UAV including: air vehicle, MPCS, mission payload, data link, launch and recovery and logistics support.

APPENDIX B: ACRONYMS

ACAT	Acquisition Category
ADT	Air Data Terminal
AGL	Above Ground Level
ASN(RD&A)	Assistant Secretary of the Navy (Research, Development and Acquisition)
ATARS	Advanced Tactical Air Reconnaissance System
BDA	Battle Damage Assesement
BW	Bandwidth
CALS	Computer-aided Acquisition Logistics Support
CBT	Computer Based Training
CDL	Common Data Link
CDR	Critical Design Review
CFT	Contractor Flight Test
C^3I	Command, Control, Communications and Intelligence
COEA	Cost and Operational Effectiveness Analysis
CONOPS	Concept of Operations
CR	Close Range
CSC	Conventional Systems Committee
DAB	Defense Acquisition Board
DARPA	Defense Advanced Research Projects Agency
DEA	Data Exchange Agreement
DEA	Drug Enforcement Administration
DoD	Department of Defense
DT	Development Test
DT&E	Development Test and Evaluation
ECM	Electronic Countermeasures

APPENDIX B:
ACRONYMS

E&MD	Engineering and Manufacturing Development
EMI	Electromagnetic Interference
EO	Electro-optical
ESM	Electronic Support Measures
EW	Electronic Warfare
EXCOM	Executive Committee
FCT	Foreign Comparative Testing
FLIR	Forward Looking Infrared
FLOT	Forward Line of Own Troops
FMS	Foreign Military Sales
FRP	Full Rate Production
FSD	Full Scale Development
GCS	Ground Control Station
GCU	Ground Control Unit
GDT	Ground Data Terminal
GFT	Government Flight Test
GPS	Global Positioning System
HMMWV	High Mobility Multipurpose Wheeled Vehicle
I&C	Interoperability and Commonality
IDL	Interoperable Data Link
IFF	Identification Friend or Foe
ILS	Integrated Logistics Support
IMU	Inertial Measurement Unit
IOT&E	Initial Operational Test and Evaluation
IR	Infrared
IRAD	Independent Research and Development
ISAR	Inverse Synthetic Aperture Radar
JDF	Joint Development Facility
JLA	Joint Logistics Assesment

APPENDIX B:
ACRONYMS

JIIs	Joint Integration Interfaces
JL-COE	Joint Logistics Center of Excellence
JLMIS	Joint Logistics Management Information System
JROC	Joint Requirements Oversight Council
JSIPS	Joint Service Imagery Processing System
JTIDS	Joint Tactical Information Distribution System
JTC/SIL	Joint Technology Center/Systems Integration Laboratory
JTSC	Joint Technology Steering Committee
JUSC	Joint UAV Steering Committee
km	Kilometer
LADAR	Laser Radar
lb	Pounds
LRP	Low Rate Production
LUT	Limited User Test
MAGTF	Marine Air-Ground Task Force
MAVUS	Maritime Vertical Takeoff and Landing Unmanned Aerial Vehicle System
MEF	Marine Expeditionary Force
MIAG	Modularized Integrated Avionics Group
MNS	Mission Need Statement
MOA	Memorandum of Agreement
MOU	Memorandum of Understanding
MPCS	Mission Planning and Control Station
MPS	Mission Planning Station
MR	Medium Range
MS	Milestone
MTI	Moving Target Indicator
NAVAIRWARCENACDIV IND	Naval Air Warfare Center Aircraft Division, Indianapolis, IN

APPENDIX B:
ACRONYMS

NAVAIRWARCENACDIV TRN	Naval Air Warfare Center Aircraft Division, Trenton, NJ
NATO	North Atlantic Treaty Organization
NBC	Nuclear, Biological and Chemical
NSA	National Security Agency
O&M	Operations and Maintenance
ORD	Operational Requirements Document
OSD	Office of Secretary of Defense
OT	Operational Test
OT&E	Operational Test and Evaluation
PEO	Program Executive Officer
PEO(IEW)	Program Executive Officer for Intelligence and Electronic Warfare
POM	Program Objective Memorandum
RDT&E	Research, Development, Test and Evaluation
RSTA	Reconnaissance, Surveillance and Target Acquisition
RVT	Remote Video Terminal
RWR	Radar Warning Receiver
SAR	Synthetic Aperture Radar
SBIR	Small Business Innovation Research
SDT	Surface Data Terminal
SEI	Specific Emitter Identification
SEIA	Systems Engineering Integration Agent
SIGINT	Signals Intelligence
SIMNET	Simulation Network
SMS	Ship Motion Simulator
SR	Short Range
SSG	Special Study Group
STANAVFORLANT	Standing Naval Force Atlantic

APPENDIX B:
ACRONYMS

SURVIAC	Survivability Information and Analysis Center
TAMPS	Tactical Aircraft Mission Planning System
TEMP	Test and Evaluation Master Plan
TET	Technical Evaluation Test
UAV	Unmanned Aerial Vehicle
UAV JPO	Unmanned Aerial Vehicles Joint Project Office
USA	United States Army
USAF	United States Air Force
USMC	United States Marine Corps
USN	United States Navy
USD(A)	Under Secretary of Defense (Acquisition)
VLC	Very Low Cost
VTOL	Vertical Takeoff and Landing

APPENDIX C
ADVANCED TECHNOLOGY PLANNING

The technologies reflected in Figure 43 on page 50 are an initial estimate of the types of subsystems that will be developed for UAV application. The generations depicted by the columns in Figure 43 reflect a difference between systems which the UAV JPO is developing now, and those it is planning for in the future. Of the ten areas depicted in Figure 43, the UAV JPO has identified two ongoing research projects by other agencies which have a direct bearing on UAVs. The first project is being managed by USA's PEO(IEW). Its purpose is to develop a MTI radar that could be employed from UAVs. The second is an Independent Research and Development (IRAD) program to develop a low cost, lightweight, interoperable data link. These projects can be construed as first generation technology initiatives. They are discussed in more detail below, showing planned schedules. Other first generation technologies such as the heavy fuel engine and modular avionics packages, shown in Figure 43 as first generation technologies in the areas of propulsion and avionics respectively, are part of the commonality component program discussed in Section V. In addition, the UAV JPO is aware of several Small Business Innovation Research (SBIR) projects which have been funded by the individual Services and DARPA. These projects are included in the charts and discussions concerning the UAV JPO's POM 94 plan for technologies. The UAV JPO has not initiated any programs in the advanced technology area prior to the POM 94 submission due to funding constraints.

	FY92	FY93	FY94	FY95	FY96	FY97
MTI Radar Payload	System Definition		SPEC Development & E&MD			
Low Cost Interoperable Data Link	DT		B SPEC			

UAV Generation I Technology Plan

MTI Radar Payload

Concept developments and technology demonstrations for small MTI battlefield surveillance radar payloads were ongoing when the UAV JPO was established in 1988. PEO(IEW) and the Harry Diamond Laboratory, with cooperation by Lincoln Laboratories, concentrated on system assessments of radar components, MTI signal processors, and combat information displays to determine specifications for UAV MTI radar payloads. All necessary MTI systems components, from airborne radar units to ground combat displays, with many variations of features, were tested in field combat exercises. The UAV JPO participated in this project in an advisory role, helping to establish mutual understanding regarding UAV payload carrying capabilities/ limitations and anticipated MTI radar system performance requirements. This technology assessment effort is now completed and the lessons learned will be applied to a development program expected to begin in FY94 .

Low Cost Interoperable Data Link

This technology development and demonstration provides a family of lightweight, long range, survivable, and interoperable data links at reasonable cost for the entire range of projected UAV combat activities. Current technology data links, which are compatible with projected UAV mission profiles, threat exposures, and performance requirements (e.g., data rate), are very expensive for mid to high intensity conflicts. Systems compatible with low intensity conflict situations lack extended bandwidth, interoperability with preferred link standards, and survivability. This program complies with recently formalized DoD policy (OSD/C^3I, December, 1991) that standardizes reconnaissance sensor data links. Due to lack of dedicated advanced technology resources, this program has been implemented as a cooperative IRAD program with industry. Two prototype airborne data terminal prototypes have been completed. The UAV JPO, in cooperation with PEO(IEW), will flight test these units to determine how well they meet overall battlefield requirements.

Generation II and III Technology Plans

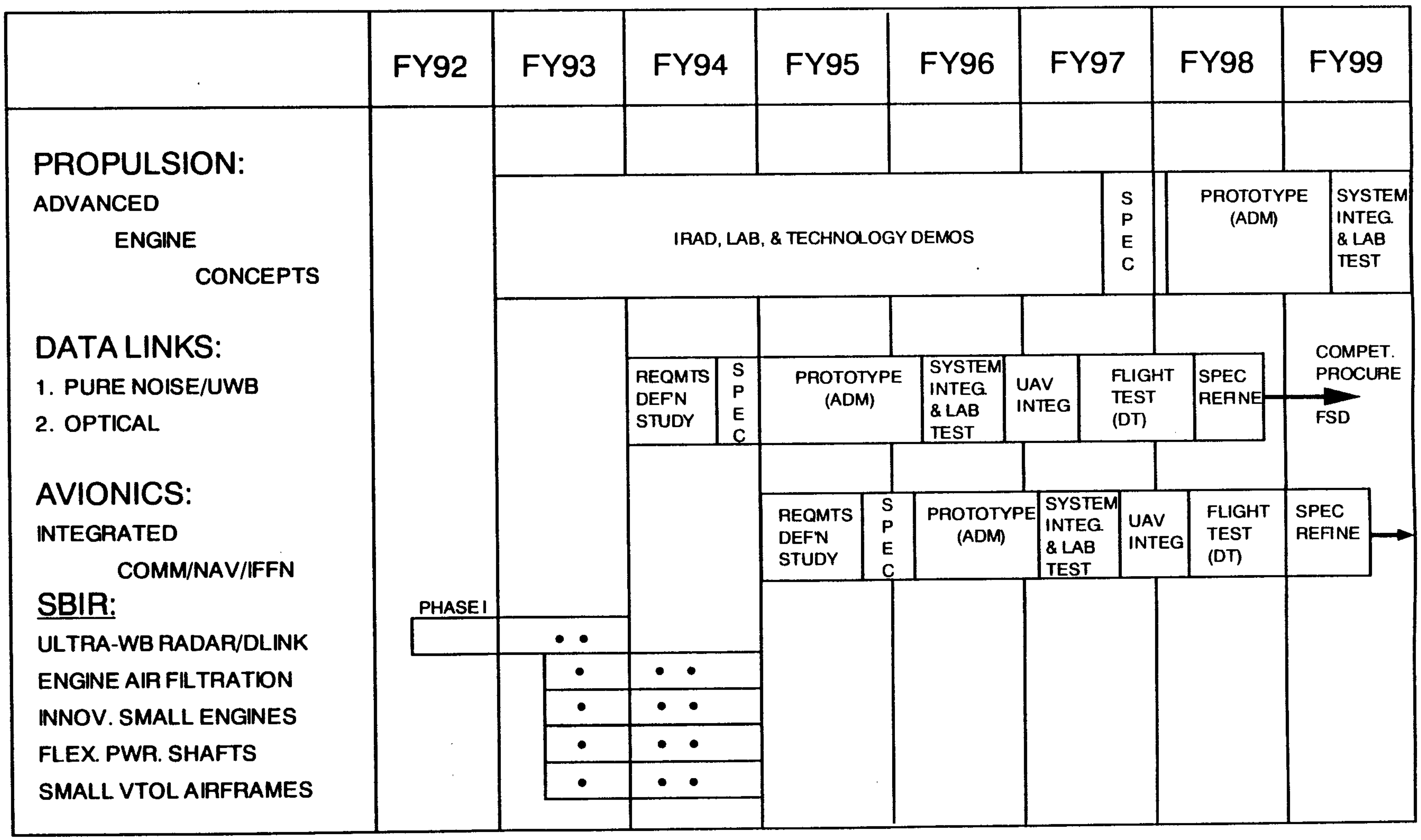
The UAV JPO has a robust technology development plan in place for the FY94 POM process. As a result of the coordination efforts with the Services and DARPA, it is expected that many new projects will be added to those being monitored by the UAV JPO. Conspicuous by their absence are advanced technology initiatives in the areas of air vehicle/airframe, launch and recovery, human engineering, and computational subsystems. The UAV JPO is already investigating tilt rotor and slave-tandem free wing concepts. Additionally, the CR program is conducting six air vehicle demonstrations.

In the area of launch and recovery, a generation I/II technology is part of the commonality component program. No future effort will be initiated until this program matures and more is known regarding requirements. Due to a lack of funds, there are no plans for specific projects in human engineering or computational subsystems. It is envisioned that the UAV JPO will monitor and capitalize on research done by other agencies in these two areas. For the remainder of the areas, the UAV JPO plans to begin technology initiatives in the coming years. The following discussions highlight these plans.

Propulsion

All Services need engines which will operate on standard heavy fuels. High specific fuel consumption, high power density, and for some classes of UAVs, very high altitude operations will be required. This combination of performance characteristics requires the development of a family of UAV engines, preferably modular, with as many common components and subassemblies as practicable. This basic design objective would produce/promote economies in engine life cycle costs, reduced logistics support requirements, and increased operational effectiveness. The advanced engine concepts program takes advantage of industry initiatives and advances to plan a series of technology demonstrations, which build toward the most practical and

UAV ADVANCED TECHNOLOGY PROGRAMS
AIR VEHICLES



• PHASE I, IF SELECTED   • • PHASE II, IF IMPLEMENTED

economic set as specification for development of prototype engines. Several different classes of engine applications will be prototyped and laboratory tested in a multi-phased program. The most promising of these may be continued into flight testing, the results of which will assist in selecting superior alternatives as procurement specifications for a family of common component heavy fuel engines.

Data Links

The advanced technology data links program responds to the need for reliable control of and data interchange with future air vehicles and their payloads in increasingly hostile threat environments. Low-cost, lightweight, long range data links for the entire spectrum of projected UAV operational environments is the goal. These data links must have sufficient jam resistance to operate in extremely dense and hostile (including active jamming) electromagnetic environments. There must also be data link interoperability among the various categories of UAVs and other battlefield C^3I systems. Technology development for a low-cost version of the DoD Interoperable Data Link (IDL)/Common Data Link (CDL) was discussed above. More advanced technologies, such as millimeter wave, laser, and ultra-wide band communications, offer improved potential in reducing data link signatures, increasing jam resistance, and providing more flexible data bandwidths for advanced sensors. Two transmission methods are being studied: "pure noise" ultra-wide band and optical (laser). Both technologies will be examined during a requirements definition study designed to identify and match proposed future UAV systems' applications with advanced data link component development achievements. Two or more data link designs will be prototyped and tested in a multi-phased program with the results providing inputs for use in establishing specifications for a future family of common UAV data link components.

Avionics

The DoD Joint Integrated Avionics Working Group (JIAWG) is sponsoring development of integrated multi-functional avionics systems to perform all communications and signal processing functions. This program provides a single programmable electronics unit for integrated communications, navigation, and identification of friend or foe (IFF) avionics functions. The commonality component program has already capitalized on this initiative with the development of the MIAG for UAVs. Investigation concerning extension of these principles to modules for the airborne component of the data link and fiber optic bus upgrades to the MIAG is underway.

Multi Mode EO-IR Payload

This program will develop a prototype multi-spectral sensor capable of operation in the IR band as a FLIR, with a second mode of active/passive operation in the ultra-violet (UV) spectral bands (i.e., a laser radar or LADAR). These multiple modes of operation, including interfaces for sensor cross-cueing, will:

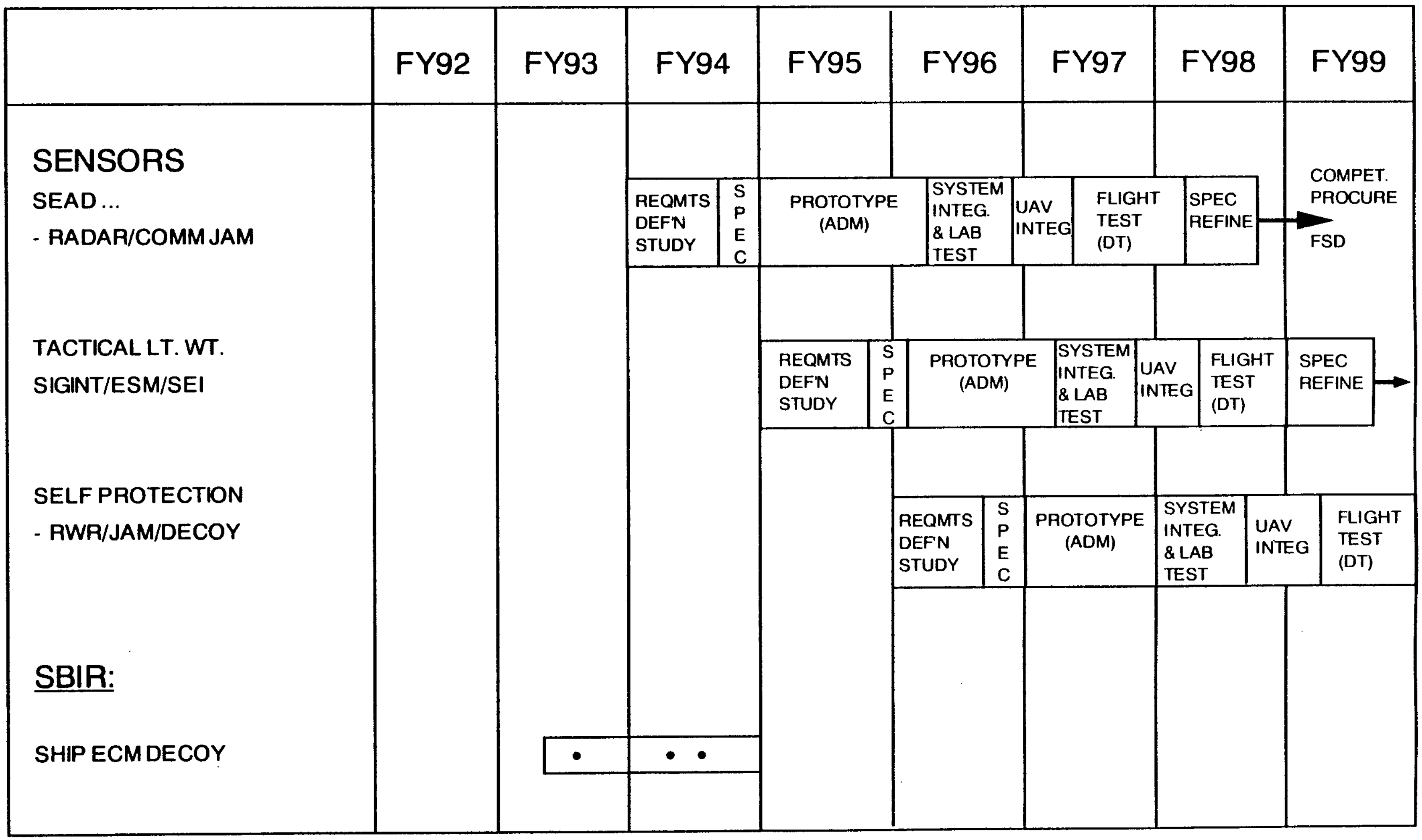
- reduce susceptibility to enemy countermeasures
- increase sensor effectiveness (especially passive operation modes)
- allow mission flexibility by interaction with other sensors.

UAV ADVANCED TECHNOLOGY PROGRAMS
PAYLOADS (1 OF 2)

	FY92	FY93	FY94	FY95	FY96	FY97	FY98	FY99
SENSORS								
MULTI-MODE RADAR — SAR/MTI/ISAR	REQMTS DEF'N STUDY; SPEC	PROTOTYPE (ADM)	SYSTEM INTEG. & LAB TEST; UAV INTEG	FLIGHT TEST (DT)	SPEC REFINE →	COMPET. PROCURE FSD		
MULTI-MODE EO-IR — EO/IR/LADAR			REQMTS DEF'N STUDY; SPEC	PROTOTYPE (ADM)	SYSTEM INTEG. & LAB TEST	UAV INTEG; FLIGHT TEST (DT)	SPEC REFINE →	COMPET. PROCURE FSD
MULTI-FUNCTION RF — RADAR/DL/ECM				REQMTS DEF'N STUDY; SPEC	PROTOTYPE (ADM)	SYSTEM INTEG. & LAB TEST	UAV INTEG; FLIGHT TEST (DT)	SPEC REFINE →
SBIR: SENSOR DATA BW COMPRESSION		PHASE I	PHASE II • •					

• • IF IMPLEMENTED

UAV ADVANCED TECHNOLOGY PROGRAMS
PAYLOADS (2 OF 2)



• IF SELECTED
• • IF IMPLEMENTED

This program will be developed in four phases as previously explained for the multi-mode/MTI radar payload program:

- system definition/initial specifications
- prototype
- system integration
- flight testing/refined specifications

Multi-Function RF Payload

This payload will increase mission flexibility and contribute to air vehicle survivability by performing a variety of tasks associated with radio frequency transmission, reception and signal processing. These functions include radar, ECM and data link, all performed by a programmed reconfiguration of standard "building blocks" under advanced microprocessor control. It is envisioned that advanced UAVs could be equipped with two or more of these multi-function payloads, thereby providing redundancy or "backup" and/or system simultaneous operation in several modes/functions. This program will be developed in phases as previously explained for the multi-mode/MTI radar payload and multi-mode EO-IR payload programs.

Suppression of Enemy Air Defenses (SEAD) - Radar/Communications Jammer Payload

This program will develop an ECM jamming package required for missions that assist other UAVs, strike aircraft, or its own penetration of difficult enemy air defense environments. The package will use advanced technology for new generation components and system integration features. It will provide many of the ECM functions now associated with larger, high-power jamming systems located far behind the battle area. Operated much closer to many threat systems, it will be able to employ modern, low power techniques to disrupt targeted threat air defense assets.

This program will be developed in the four phases previously discussed above.

Tactical Light Weight SIGINT/ESM Payloads

These payloads will provide signal detection, identification and location of electromagnetic emitters. Through advanced technology modules and onboard processors, SIGINT and ESM functions are performed on signals received by these payloads. Target signal data and control signals for these on-board systems are transmitted and received via data links with other collectors and the appropriate data processing stations.

This program will be developed in the four phases previously discussed above.

Self Protection RWR/Jammer/Decoy Payload

This payload is required to promote survivability of present and future generation UAVs in hostile air defense environments. Intended for operation in several modes, the package will provide for radar warning, defensive self-screening jamming, and

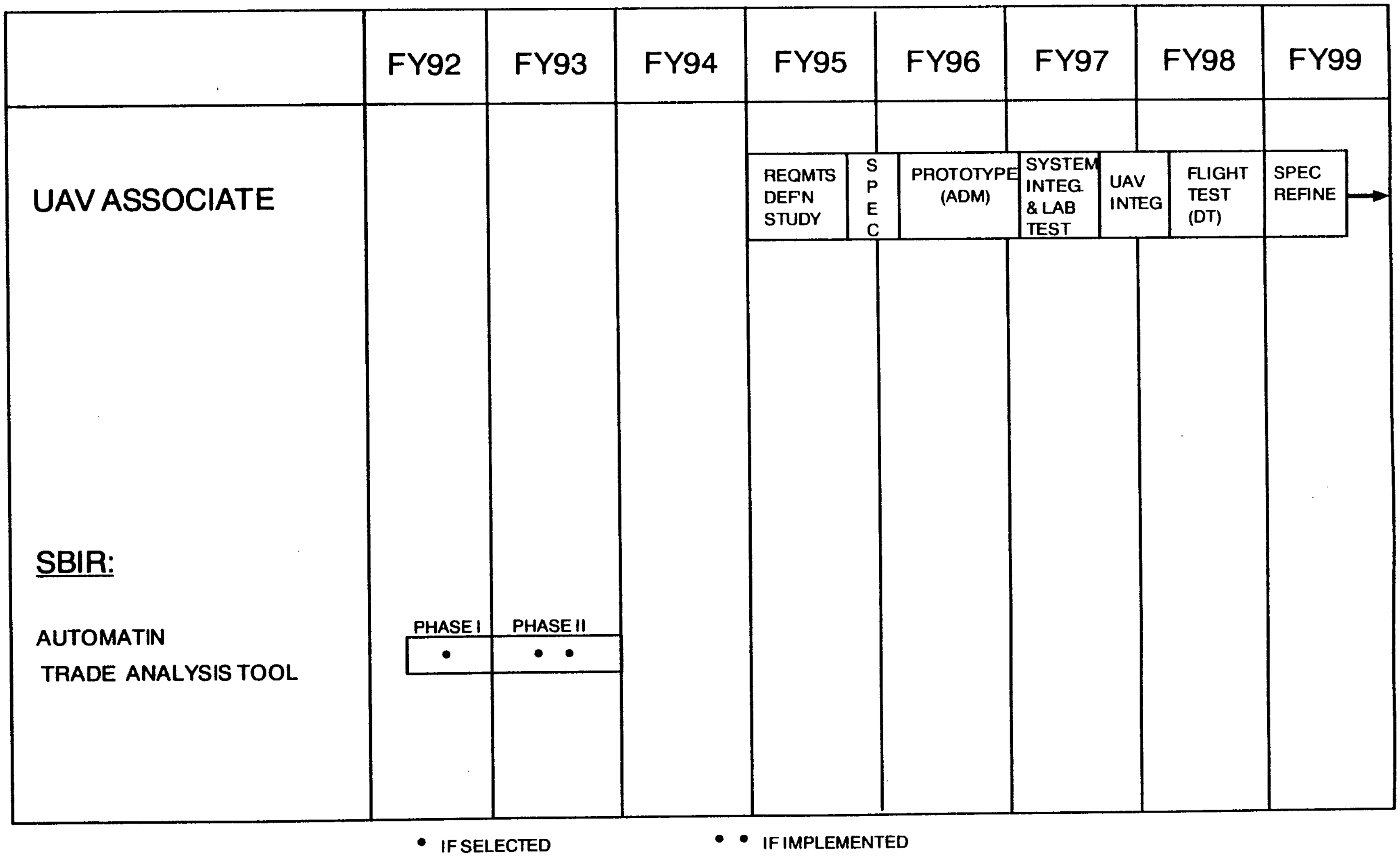
electronic decoying functions. This program will integrate, in an affordable manner, the capabilities of several separate EW avionics systems with respect to size, weight, and power supply. This self-protection package may become part of the standard avionics suite carried onboard many advanced UAVs.

This program will be developed in the four phases previously discussed.

UAV Associate

The MPCS is the principal interface with the UAV system for operator(s). Its design influences the number of operators required for a particular UAV system, their skill and education levels, and their associated training requirements. Tradeoffs can be made in terms of increasing the number and complexity of operations which are handled by the MPCS, as opposed to being performed by operator(s). Baseline designs for the MPCS involve software reconfigurable workstations with some degree of mission planning capability. For the advanced technology UAV Associate program, expert system technology will be used to reduce operator workload and simplify tasking. Development of automated performance aids, modeled after the manned aircraft pilot's Associate program, will provide substantial benefits. Such aids could include rapid automated mission planning, replanning given designated mission goals/limits/rules, automated target recognizers, malfunction analyzers, advanced anticipatory automated warnings, and regressive use of functional parts of a battle damaged UAV to recover an otherwise "lost" mission. This work will take advantage of prior efforts under DARPA's Strategic Computing Program, particularly the manned aircraft "Pilot's Associate" program, and other related efforts such as the Robotic Air Vehicle, Sensor Driven Airborne Replanner, and Field Trainable Mission Adaptable UAVs programs. The multi-phased UAV Associate program will implement a field deployable prototype capability to demonstrate and test functions selected by the initial requirements study. This evaluation capability will be used in actual flight tests to determine appropriate requirements for incorporation into a future common MPCS specification.

UAV ADVANCED TECHNOLOGY PROGRAMS
WORKSTATIONS/MMI



APPENDIX D
PAYLOAD TECHNOLOGY ASSESSMENT

Each section of this annex provides technical information on a type of mission payload. After a brief explanation of the technology and its applications, a table of the technical parameters and system characteristics is presented.

The format of the matrices is such that the name, manufacturer, military type number and a general description of the system's function appears in the far left column. the three columns on the far right represent an estimate of the payload's readiness for inclusion on a UAV, and the missions for which it is likely to be most useful. The letter code appearing on the "UAV Capability Factor" column symbolizes the following:

G = System evaluated as ready for inclusion on a UAV; minimal integration required.

Y = System evaluated as needing redesign for use on a UAV, e.g., downsizing.

R_1 = System not suitable for UAV use.

R_2 = System judged as requiring extensive repackaging for use on a UAV.

The remaining columns contain data elements of importance in the consideration and selection of a system type for UAV mission payload use.

UAV PAYLOAD CATEGORIES

MISSIONS		PASSIVE IMAGE GENERATING SENSOR TV/FLIR/IRLS	ACTIVE IMAGE GENERATING SENSOR RADARS	SPECIAL ACTIVE ILLUMINATOR SENSOR LASER DESIGNATOR	PASSIVE DIRECTION FINDER SIGINT/ESM RECEIVER	SPECIAL PURPOSE PAYLOADS MET/NBC/MINE DETECTION/ ASW RECEIVER	EW PAYLOADS ECM/DECOY	COMMUNICATIONS RELAY VOICE/DATA RELAY	SERVICE (A/MC/ MISSION N/AF)
1	COMMAND & CONTROL							X	
2	INTELLIGENCE	X	X		X	X			
3	FIRE SPT/NGFS/OTHT/ ASUW/BDA	X	X	X	X	X		X	
4	MINE DEFENSE	X	X			X			
5	AMPHIBIOUS SPT	X	X	X	X	X	X	X	
6	CLOSE COMBAT/ ASSAULT SUPPORT	X	X	X	X	X	X		
7	AIR DEFENSE/AIR CONTROL	X	X		X		X	X	
8	MANEUVER/TACTICAL MOBILITY/SEARCH & RESCUE	X	X			X		X	
9	TACTICAL AIR SPT/AVIATION/ SEAD/AIRINTERDICTION	X	X	X	X	X	X	X	
10	AIR RECONNAISSANCE/ COUNTER AIR	X	X		X	X		X	
11	ELECTRONIC WARFARE				X		X		
12	ASW SUPPORT	X	X		X	X		X	
13	SPECIAL OPERATIONS	X			X	X		X	

SERVICE ANTICIPATED MISSION AND PAYLOAD CATEGORY CORRELATION

FORWARD LOOKING INFRARED SENSORS

Forward Looking Infrared (FLIR) sensors are mechanically scanned devices that convert radiation from the infrared spectral region to the visible spectrum in real time. These sensors provide two dimensional imagery comparable to that of conventional television. Their field of view and magnification can be varied by appropriate optics. Thermal imaging devices surpass other passive electro-optical sensors with their capability for day and night operation. They achieve high contrast renditions of targets through atmospheric windows that are wider than those of visual sensors. A minor disadvantage of FLIRs is the loss of three dimensional contour information because of the lack of shadows. FLIR sensors are capable of detecting large (tank-sized) targets at long range if the target's temperature contrasts sufficiently with background temperatures.

FLIR SENSORS

Name & Manufacturer	FOV (AZ x EL)	Spatial Resolution (AZ x EL)	Field of Regard (degrees)	Thermal Resolution (NEDT)	Detectors Type & No.	Total Weight (lbs)	Power (watt)	Volume (inches)	UAV Compatibility Factor*	Anticipated Missions*	Maturity
AN/AAQ-17 Texas Instruments	4° x 3° (NFOV) 18.2° x 13.7° (WFOV)	0.134 x 0.2 MR	AZ +/-200° EL + 15° to -105°		MCT 8-12	143			Y	2-10 12, 13	Production Deployed on AC-130H
Lightweight FLIR Westinghouse	3° x 4° (NFOV) 15° x 20° (WFOV)	0.22 x 0.22 MR	AZ +/-60° EL 0°, -6°	0.15°	PTSI 3-5 244 x 320 Focal Plane	92	675	6 3/4 Dia x 22 ht	G	2-10 12,13	Production Deployed
Micro FLIR Kollmorgen	3° x 2.2° (NFOV) 15° x 7.5° (WFOV)	0.135 x 0.108 MR (N) 0.44 x 0.35 MR (W)	AZ 360° EL + 20° to -120°	0.35°C	MCT 8-12 8 Bar Serial Scan	55	275	14 Dia	G	2-10 12,13	NDI on MAVUS
Kollsman FLIR 120 Kollsman	2.7° x 3.6° (NFOV) 11.1° x 7.5° (WFOV)	0.2 x 0.2 MR (N) 0.44 x 0.35 MR (W)		0.15°C	MCT 8-12 120 x 1 EL x AZ	54			Y	2-10 12,13	ND on Tripod Version
FSI 2000G FLIR Systems	5° x 2.7° (NFOV) 15° x 28° (WFOV)	0.25 x 0.25 MR (N) 1.4 x 1.4 MR (W)	AZ 360° EL 90° to -180°		MCT 8-12 Detectors	80			G	2-10 12, 13	Deployed
AN/AAQ-16 Hughes	6.5° x 4.9° (NFOV) 30° x 40° (WFOV)		AZ +/-210° EL 87° to -180°		PTSI 3-5 160 Detectors	100	644	12 Dia 14 ht	G	2-10 12, 13	Deployed
PRSI Micro FLIR 7003 Loral Fairchild	3.5° x 4.6° (NFOV) 6.9° x 9.2° (WFOV)		AZ 360° EL 0 - 90°		PTSI 3.4 - 5.5 FPA 244 x 400	18		10 x 5 x 5	G	2-10 12, 13	NDI Development
STIS MK-11 Loral	3° x 2° (NFOV) 10.8° x 7.2° (MFOV) 30° x 20° (WFOV)	0.128 x 0.151 MR (N)	AZ 360° EL 30° to -105°		MCT 8-12 14 x 2 Sprite Serial	75	300	14 Dia 20 ht	G	2-10 12,13	Deployed
PRSI Mini FLIR LF CCD 2447 Loral	3.8° x 2.3° (NFOV) 15.4° x 9.3° (WFOV)			0.2°C	PTSI 3-5	20	60	3.6 cu. ft.	G	2-10 12,13	NDI Development
IRTV-445G Inframetrics	5.2° x 7.0° (NFOV) 24° x 28° (WFOV)	0.45 x 0.60 MR (N) 0.8 x 2.4 MR (W)	AZ 360°	0.1°C	MCT 8-12 2 x 2 Serial Scan	71	50	9 Dia 13.5 ht	G	2-10 12,13	Production
AN/DSQ-49 Loral	2.8° x 2.1° (NFOV) 6.4° x 4.8° (MFOV) 14.4° x 10.8° (WFOV)		AZ 360 EL 19° to -90°		MCT 8-12 2 x 14 Serial Scan	54 w/o Laser	199		G	2-10 12,13	Prototype on AQUILA

* See pages 79 and 80 for explanation

FLIR SENSORS

Name & Manufacturer	FOV (AZ x EL)	Spatial Resolution (AZ x EL)	Field of Regard (degrees)	Thermal Resolution (NEDT)	Detectors Type & No.	Total Weight (lbs)	Power (watt)	Volume (inches)	UAV Compatibility Factor	Anticipated Missions	Maturity
WF 360 Westinghouse	3.6°x 2.7°(NFOV) 14.8°x 11.1°(WFOV)	0.22 x 0.158 MR	AZ 360° EL + 30° to -75°	0.1°C	MCT 8-12 120 x 1 Detectors	205	500	16 Dia 22 ht	Y	2-10 12, 13	Production
(NLOS) FLIR Hughes	3.5° x 4.2°(NFOV) 10° x 14°(WFOV)		+/-27°AZ & EL		PTSI 3.4 - 4.2 FPA 244 x 400	10		10.8 x 7 x 7	G	2-10 12,13	NDI Development
Compact FLIR FLIR Systems	2°x 3° 6°x 9°		fixed		MCT 8-13 Scanner	25-50		10 x 10 x 6	G	2-10 12,13	NDI Development
HP FLIR Pilkington	1.9°X 2.9° 6°x 9°		AZ +/- 100° EL +/- 10°		MCT 8-12 Scanner	35	65	12 x 10 x 7	G	2-10 12,13	NDI Development
GFS-3 Honeywell	3°x 2°(NFOV) 10.8°x 7.2°(MFOV) 30°x 20°(WFOV)	.18 x .125 MR .64 x .45 MR 1.8 x .125MR	360° +20°to -105°	.5°C @ x 1.1 CY/MR 1.0°C @ x 4 CY/MR	Sprite Detector	70	300	14 dia 20 ht	G	2-10 12,13	Production
STA-360 TI	5.3°x 3.3°(NFOV) 15.3°x 9.6°(WFOV)	.28 MR .86 MR	360° +30°to -90°			75	300	14 dia 17.25 ht	G	2-10 12,13	Production
FORD/FMPS	2.6°x 3.5° 13.5°x 18°		360° +19°to -90°		MCT 8-12 Scanner	42	350	18 x 13.2 x 13.2	G	2-10 12,13	NDI
					FOREIGN						
MOSP IAI	1.7°x 1.3° 4.6°x 3.5° 25°x 19°	.06 MR	360° +15°to -105°	<0.1°C	8-12	80	240	14 dia 21.6 ht	G	2-10 12,13	Production
MKD-400 TADIRAN	3°x 2° 10.75°x 7.25° 2.5°x 16.7°	.13 x .17 MR	360° 0, -80°	.2°C @ x 2.8 CY/MR	MCT 8-12 1 x 14 detectors	55	280	12.6 dia 18.7 ht	G	2-10 12,13	Production
M2TIS/G-47 Rafael	1.96°x 1.53° 7°x 5.3° 24°x 18	.065 x .111 MR	+/-175 80° to -80°	1°C @ x 7.5 CY/MR		160		18.8 dia 26 ht	Y	2-10 12,13	Production
IR-18 BARR & Stroud	5.3°x 3.54° 21.2°x 14.2°	0.2 MR 0.8 MR	360° 50° to -120°			104	150	14.8 dia 22.3 ht	G	2-10 12,13	Production

INFRARED LINE SCANNER SENSORS

Infrared line scanner (IRLS) sensors are fixed-point, down-looking devices that provide high resolution imagery over a wide field of view. The sensors produce a continuous strip of data with a much wider field of view than FLIRs. IRLS devices use an infrared detector in conjunction with an oscillating mirror. The mirror sweeps the focus across the detector perpendicular to the line of flight while the forward motion of the air vehicle advances the scan line. The high resolution imagery of IRLS sensors surpasses FLIR imagery in both resolution and the size of the area covered. A disadvantage is the wide bandwidth required for transmission of data from the sensor to the ground station. These large quantities of data can exceed the capabilities of current data links. Since IRLS sensors produce high resolution imagery, data compression techniques are difficult to apply. Only low ratio compression algorithms have successfully reduced IRLS data rates while maintaining the sensor's resolution.

INFRARED LINE SCANNER (IRLS)

Name & Manufacture	Field of View	Spectral Region	NETD °C	V/H (rad/s)	Scan Rate Scan/sec	Volume (cu. ft)	Weight (lbs)	Power (w)	Spatial Resolution (mr)	UAV Compatibility Factor	Anticipated Missions	Maturity
D-5 RC Honeywell	120/60 deg	8 - 12	<0.2	0.05 - 2.4	200 400	5.9	244	651	0.5 x 0.25	Y	2-10, 12, 13	Deployed on TACAIR
D-5 RC/SEU-A Honeywell	120/60 deg	8 - 12	<0.2	0.05 - 2.4	200 400	5.0	208	795	0.5 x 0.25	Y	2-10 12, 13	Deployed
D-500 Honeywell	120/60 deg	8 - 12	<0.2	0.05 - 2.4	200 400	6.9	164	650	0.5 x 0.25	Y	2-10 12, 13	Deployed
ATARS Loral	140/70 deg	8 - 14	<0.2	0.04 - 5.0	200 400	1.8	76	400	0.5 x 0.25	G	2-10 12, 13	Prototypes
ATARS/SEU-A Loral	140/70 deg	8 - 12	<0.2	0.04 - 5.0	200 400	3.7	144.3	545	0.5 x 0.25	G	2-10 12, 1	Prototypes
IIS	180 deg	8 - 12	<0.45	0.5 - 5.0	154.6	10.7	381	1670	.219	R1	2-10 12, 13	Production
Mini IRLS Loral	180 deg	8 - 12	<0.45	0.0 - 0.7	175	0.2	15	65		G	2-10	NDI Development
RPV-800 TI	150 deg	8 - 12	0.4			13.1 x 8.4 x 9.5 in	30	200	0.5	G	2-10 12, 13	NDI Medium Range
AMIDARS CAI	60-120 deg	8 - 12		<1.0	85.73	22 x 18 x 16 in	65	600	0.5 or better	G	2-10 12, 13	Prototypes
Barr & Stroud	100 deg			0.48		12 x 7 x 8 in	15	250	0.4	G	2-10 12, 13	NDI
Vinten 4000	180 deg			5.0		11 x 8 x 9 in	44	256	0.5 or better	G	2-10 12, 13	NDI
Vinten	180 deg			2.5		11 x 8 x 9	29	250	0.5 or better		12, 13	

LASER RANGEFINDERS AND DESIGNATORS

Laser rangefinders bounce laser pulses off targets and time the round trip to determine the range. They are extremely accurate and can be coupled to a visual display system which exhibits the target and provides a digital readout of its range. Laser rangers lose their accuracy if the diameter (or spot) of the radiated beam exceeds the size of the target. The resultant spill over of the beam can bounce off background objects and produce erroneous range information. Laser designators operate similarly to rangefinders, bouncing their coded pulses off a target for detection and lock-on by a weapon's seeker. Since sufficient laser energy must reflect from the target to the seeker, the beam's divergence, stability, and accuracy all become essential factors in attaining successful lock-on.

LASER RANGER/DESIGNATOR

Name & Manufacture	Emission Wavelength (micron)	PRF	Pulse Width (Ns)	Output Energy (mj)	Beam Divergence (mrad)	Weight (lbs)	Size (in)	Resolution Power (wt)	Spatial Compatibility Factor	UAV Anticipated Missions	Maturity
Night Eagle Laser Designator Loral/Litton	1.06 Nd:yag					8.0	15 dia 6 ht	175	G	3, 5, 6, 9	Prototypes on AQULIA
Litton Laser Marker	1.06 Nd:yag	Band I & II	20 ± 5		0.5	9.5	5.5 x 8.5 x 10	156	G	3, 5, 6, 9	NDI Development
McDonnell Douglas Laser Ranger/ Designator	1.06 Nd:yag	0 - 20 Hz	9 - 30	200	>0.09	15	400 cu in	200	G	3, 5, 6, 9	Prototypes on F-18 & Helos
McDonnell Douglas Laser Illuminator		13.1 Hz				16		22	G	3, 5, 6, 9	Production
MOSP Laser Designator	1.06 Nd:yag	20 Hz		80	0.45				G	3, 5, 6, 9	NDI

RF ACTIVE SENSORS (RADARS)

MOVING TARGET INDICATOR RADAR

Moving Target Indicator (MTI) radar uses Doppler frequency shifts to detect moving targets. Unlike traditional radar, MTI establishes a reference frequency by diverting a small portion of its transmitted pulses to its receiver. It then subtracts the reference frequency from the returning echo to determine the Doppler shift. Movement in the field of view is subsequently highlighted against the static background clutter. MTI provides all-weather, high resolution imagery of moving targets, but loses stationary targets in the background clutter.

SYNTHETIC APERTURE RADAR

Synthetic Aperture Radar (SAR) uses Doppler processing to produce high resolution imagery of stationary targets in all weather conditions. SAR uses the motion of its platform to electronically lengthen its antenna and thus enhance the resolution of its imagery. It can maintain high quality resolution regardless of altitude or range to the target and is well suited to mapping and wide area surveillance. While its platform flies along a straight path, the SAR's antenna beam scans a continuous swath over the ground and produces a strip map of the terrain.

INVERSE SYNTHETIC APERTURE RADAR

Inverse Synthetic Aperture Radar (ISAR) depends on the random motion of its targets to generate a Doppler image. This process gives it relatively long range and, with special near real time processing, functional resolution. When operating in the Planned Position Indicator (PPI) mode, ISAR tracks numerous targets in a manner similar to MTI radar. When changed to the spotlight imaging mode, ISAR locks onto a designated target, tracks it and transmits imagery of the target's profile. ISAR has the unique capability of non-cooperative target identification.

RF ACTIVE SENSORS (RADARS)

Name & Manufacturer	Type	Frequency	Antenna Beam	Swath Size and Resolution	Antenna Scan Option	Detection Range	Weight (lbs)	Size (cu. ft.)	Power (w)	UAV Compatibility Factor	Anticipated Missions	Maturity
Harry Diamond Lab	MTI Track While Scan	Ku	3°x 26°	15/6/4 km footprint 50/15/30 M Reso	360° or 20°/30° Sector Scan	20 km ∂ 10 m^2 tgt	110	3 - 4	1050	G*	2 - 10	Prototypes
AIL	MTI	Ku	1.7°x 7°	15/50/100 M	360° or 90°/120° Sector Scan	20 km tgt ∂ 10 m^2 tgt	169	14	740	G*	2 - 10	NDI Prototypes
Lockheed	MTI	Ku	3°x 30°	50 M	360° or limited Sector Scan	18 km ∂ 10 m^2 tgt	125	2	1200	G*	2 - 10	NDI Prototypes
Motorola	MTI	X	3.9°	15/30 M	90°Sector Scan	20 km ∂ 10 m^2 tgt	62	4	82	Y**	2 - 10	NDI Prototypes
MSAR Loral	SAR	X	8.5°x 17°	1700 M/675 M Swath Size 3M x 3M or 1M x 1M	Fixed Antenna	10 km ∂ 10 m^2 tgt	88	1.25	470	G*	2 - 10	NDI Prototypes
APS - 137 Texas Instrument	ISAR	X	2.4°x 4°		360° or Auto Tracking Spotlight Mode	200 nmi ∂ ship sized tgt	500		4000	Y***	2 - 10, 12	Deployed or P-3 & S-3

*Exists in flyable version, approximately sized to fit on UAV; though may not need additional packaging work
**Ground portable version only, no prototype ready for flight
***Mature Technology, Lightweight and downsized version can be developed for UAV application

SIGNALS INTELLIGENCE AND ELECTRONIC SUPPORT MEASURES SENSORS

Signals Intelligence (SIGINT) and Electronic Support Measures (ESM) receivers operate passively to provide information on the location and characteristics of electromagnetic emitters. This information is provided to the operational commanders, and others, to assist them in their decision making process.

UAV SIGINT mission payloads may include: Communications Intelligence (COMINT), Operational Electronic Intelligence (OPELINT), Technical Electronic Intelligence (TECHELINT), Foreign Instrumentation Signal (FIS) and Proforma.

The requirements of interoperability, flexibility and modularity between the active UAV payloads and the passive SIGINT/ESM payloads will require a high degree of commonality for items such as: payload command/control data links, signal/information data links, electrical power, antennas, local ground based processing, remote processing, data relay between platforms, etc.

Additionally, because of the size, weight, etc. differences between each category of UAV, some of the technical requirements for the SIGINT/ESM payloads must be different. However, a high degree of commonality between these UAV payloads, and other SIGINT/ESM platforms, can be accomplished.

A cross-walk of new technologies, with current/past capabilities, available to both the intelligence and non-intelligence community programs/projects, will contribute to the development of the UAV SIGINT/ESM payloads, and possibly the other mission payloads.

SIGINT/ESM RECEIVERS

Name & Manufacture	Type	Frequency	DF Accuracy	Sensitivity	Pulse Density (ELINT) Modulation (COMINT)	Response Time or DF Rate	Weight (lbs)	Size (cu. ft.)	Power (w)	UAV Compatibility Factor	Anticipated Missions	Maturity
MEDFLI ESL	ELINT						150	5.7	1000	G*	2, 3, 5-7, 9-13	Prototype
APR-48 IBM	Radar ESM					1.25 - 3.1 sec	32.5	0.76	235	G*	2, 3, 5-7, 9-13	Prototype
ALD-11 Litton	Radar ESM						230	2.5	1700	Y**	2, 3, 5-7, 9-13	Prototype
ALR-89 E Systems	Radar ESM	2-18 Ghz	7 deg RMS				37	0.36	210	G*	2, 3, 5-7, 9-13	NDI
COMM DF Receiver E Systems	COMM DF	20 - 1500 Mhz	3 - 5 deg RMS	-105 dbm	AM/FM/CW	>5 LOB/sec	59	4	120	G*	2, 3, 5-7, 9-13	NDI
Dalmo Victor APR-39XE2	Radar ESM						36	0.42	137	G***	2, 3, 5-7, 9-13	Prototype

* Flyable version exists, approximately sized to fit on UAV; may need repackaging work
** Need additional development to downsize it to fit on UAV.
*** To be deployed on Navy/Marine Helo

RADIAC, CHEMICAL, AMD METEOROLOGICAL SENSORS

Radiac sensors locate and measure residual nuclear radiation from airborne platforms. They calculate ground dose rate levels from the air dose rates measured by the airborne sensor. The data is collected, processed and transmitted to operational units for survey and planning purposes. Most chemical agent sensors operate in a manner similar to radiac sensors--detection by sampling the actual contaminated space. FLIRs can provide a standoff detection capability by transmitting images of chemical agent clouds for spectral analysis. Meteorological sensors provide commanders with weather information needed for operational planning. By measuring barometric pressure, ambient air temperature and relative humidity, the sensor enables operators to create weather maps of the battlefield for use in delivering precision ordnance, air operations, NBC defense, etc.

RADIAC SENSOR

Name & Manufacturer	Gamma Radiation	Beta Radiation	Modes of Operation Ratemeter	Modes of Operation Dosimeter	Foot Print	Response Time &	Weight (lbs)	Size (cu. in.)	Power (w)	UAV Compatibility	Anticipated Missions	Maturity
VDR-2	.01 mR/hr- 10,00 R/hr	.01 mR/hr- 4 R/hr	.01 mR/hr- 10,000 R/hr	to 1000R	100M x 100M @ 1000ft	2-3sec + 10% over entire range	4	93	1	G*	2,5,6,8	Produc- tion

* It has been flight tested aboard helicopter flight; it will be deployed on OH - 58 KIOWA recon helo

CHEMICAL AGENTS SENSOR

Name & Manufacturer	Mode of Operation	Detection	Sensitivity	Scanning Sector	Weight (lbs)	Size (cu. ft.)	Power (w)	UAV Compatibility Factor	Anticipated Missions	Maturity
RSCAAL Brunswick Defense	Passive IR Sensing Chemical Agents are identified by their infrared spectral absorption properties	HD, L and G Agents in Vapor form	Nerve Agent: 150 MG/m2 Vesicant: 500 to 2300 MG/m2	60 deg	50	1.97		Y*	2,5,6,8	Production
Chem Sensor Army CRDEC	HD, L and G Passive IR 8-12 micron	Nerve: 90 MG/m2 Agents	360 deg Vesicant: 150 MG/m2	18	1/3	40	G**	2,5,6,8	In	Development

* Exists in Tripod mounted version; cannot detect on the move; needs additional modification before flight test.

** Under development; specifically built for UAV and ground vehicle operations; ready for flight test on Pioneer in FY93

METEOROLOGICAL (Weather) SENSORS

Name & Manufacturer	Atmospheric Pressure(mb)		Air Temperature (°C)		Relative Humidity (%)		Precipitation Intensity (in/hr)	Cloud Presence /km	Cloud Density /km	Atomsopheric Extinction * /km	Icing Conditions	Weight (lbs)	Size (cu. in.)	Power (w)	UAV Compatibility Factor	Anticipated Missions	Maturity
	Range	Resolution	Range	Resolution	Range	Resolution											
PRESSURS Lockheed Electronic Systems Co.	0-1310	0.14 (+/- 0.2%)	-40 to+60	0.3 (+/- 1.0%)	0-100	0.1 (+/- 7%)	0 to > 0.3in/hr (x0.1in/hr) Rain Trace thru Heavy Snow	7 to >30 (x0.01) +/-100ft of entry	7 to >30 (x0.01)	300 to 0.15 (x0.01)	Yes/No	32.4	840.7	109.6 (257.6) (w/deicer)	G**	2,3,7,8 9,10,13	In Development
IMETS Univ. Texas @ El Paso	350-1000		-74 to+58		0-100							-0.5	-57	1	G	All	In Development

Notes: * Atomospheric Extinction Coefficient is a measure of FLIR effectiveness/operational range

** Has own electronics management package - sensors can be deleted for smaller size/weight

MINEFIELD DETECTION SENSORS

An Infrared Line Scanner may be used to detect land minefields. Its high resolution and large range contrast the temperature gradient of exposed and embedded mines against their background. Laser radars also detect landmines, but achieve higher resolution by outlining the actual profile of mines against their background. Since the blue-green wavelengths of laser radars can penetrate sea water, they detect naval mines near the ocean's surface. Multispectral sensors locate entire minefields by analyzing their responses over wide spectral bandwidths.

MINE DETECTION
(Land/Amphibious)

Name & Manufacturer	Targets	Detector	Swath Size	Oper Altitude	Weight (lbs)	Size (lbs)	Power (w)	UAV Compatibility Factor	Anticipated Missions	Maturity
REMIDS	Pattern Mines Disturbed Soil Scatter Mines	Active Laser (Dual Polarized) with Passive IRLS			-800			R_2^{*}	3, 4, 5, 8, 13	Brassboard
CMADS Martin - Marietta		Passive FLIR	≈20 ft dia.	300 - 500 ft	45	2		R_2^{***}	3, 4, 5, 8, 13	NDI Development
AMIDARS CAI/ Recon Optical	Pattern Mines Disturbed Soil	Hg Cd Te SPRITE IRLS	60° NFOV (1.5 NMI) 120° WFOV (5.5 NMI)		75	2	600	Y***	3, 4, 5, 8, 13	Prototype
AMDASS	Mines in Surf or on Beach	Blue-Green Laser (non-eyesafe)			≈300	54		R ****	3, 4, 5, 8, 13	Brassboard
RMDS Dornier	Pattern Mines Disturbed Soil	Vis Film IR Film			75	~2	100	Y*****	3, 4, 5, 8, 13	Prototype

* — Laboratory Prototype - Self contained computers/processors
— Very good performance, could be separated into AV payload & ground processing equipment
— Test Flown UH-60

** — Very narrow FOV
— Long Search Time/Small Area
— Good Results

*** — Modest Results
— Designed as UAV Payload.

**** — Designed to find shallow water/beach antipersonnel mines for amphibious assault landings
— Proof of Concept Brassboard Prototype - no attempt to miniaturize

***** — Non Real Time, Dual Color Photo System requires several hours for film development
— Limited NATO evaluation/use

ANTI-SUBMARINE WARFARE (ASW) SONOBUOY INTERROGATION RECEIVERS

Sonobuoys aid in the detection, classification, location, and tracking of submarines. They are dropped from aircraft or dispensed from ships. Once deployed, salt water activates their battery powered mechanisms. Three types of sonobuoys support ASW operations: automatic transmitting nondirectional buoys that provide range only; command activated buoys that must be keyed by controlling aircraft; and directional command activated buoys. They can operate in a passive mode listening for contacts below the surface and transmitting coded messages above the surface upon making contact. When one or more nondirectional buoys detect a contact, directional buoys are employed to refine the contact's track. Airborne control platforms typically use active buoys to determine precise attack solutions. A special sonobuoy, the bathythermalgraph, provides thermal profiles of the ocean's layers. ASW operators use this information to determine optimum depths for sonobuoy transducers. UAV systems will act as airborne control platforms and provide data links for these sonobuoys.

ASW RECEIVER

Name & Manufacturer	Acoustic Channels Simultaneously	Frequency Channels	Freq Bands (mhz)	Sonobuoys Compatibility	Weight (lbs)	Size (lbs)	Power (w)	UAV Compatibility Factor	Anticipated Missions	Maturity
ARR-72 Flightline Electronics	31	31	162.5 - 173.5	LOFAR, CODAR, BT, RO, CASS, DICASS	150.7			Y	12	Production Deployed on P-3C
ARR-75 Flightline Electronics	4	31	162.5 - 173.5	DIFAR, DICASS	24	.46		G	12	Production Deployed on LAMPS MK 1, III, SH-3H
ARR-84 Flightline Electronics	4	99	136 - 173.5	DIFAR, LOFAR, RANGER, BT, CASS, DICASS, VLAD, CAMBS, BARRA, ERAPS, HLA, ATAC, SAR	25	.65		G	12	Prototype
ASCL ARR -78	16	99	136 - 173.5	DIFAR, VLAD, DICASS	114	1.5	418	G	12	In Development
RESDEL P3C-Update IV	54	99	136 - 173.5	DIFAR, VLAD, DICASS	90	1.9	350	G	12	In Development To be deployed on P-3C Update IV

Production Buoys

- BT, AN/SSQ-36 BATHY Thermograph
- DIFAR, AN/SSQ-53 Directional Frequency Analyze & Record
- SP, AN/SSQ-57 Special Purpose Sonobuoy
- DICASS, AN/SSQ-62 Directional Command Active Sonobuoy System
- VLAD, AN/SSQ-77 Vertical Line Array DIFAR

Development Buoys

- TSS, Tactical Surveillance Sonobuoy
- ERAPS, Expendable Reliable Acoustic Path Sonobuoy

ELECTRONIC WARFARE AND DECEPTION PAYLOADS

Electronic warfare (EW) and deception payloads perform the electronic countermeasure functions of jamming and deception. Both functions involve actions taken to prevent or reduce the threat's effective use of radars or communication systems. When countering radars by jamming, payloads raise the electromagnetic noise level by injecting external noise through the radar's antenna. The ensuing jamming obscures the radar target by immersing it in noise. Deception creates false targets by intercepting and reprocessing the radar's signal so that synthetic targets are generated and synchronized with the radar's pulses. Countermeasures employing deception are effective against state of the art radar technology such as pulsed Doppler and pulse compression techniques. Communications jammers use barrage noise to disrupt threat C^3I systems. Most jammers concentrate on a specific frequency band, but more sophisticated repeater-follower devices will actually track and jam frequency hopping systems.

EW/DECOY PAYLOADS

Name & Manufacture	Mode of Operation	RF Power (w)	Freq Range	Jamming Signals	Weight (lbs)	Size (lbs)	Power (w)	UAV Compatibility Factor	Anticipated Missions	Maturity
SSQ-95 AEB Dalmo Victor	Decoy				50	1.5	200	G	5, 6, 7, 9, 11	Prototype Deployed on MAVUS
SMARTV Naval Avionics Center	Comm Jamming Search/Blind Jam/ Auto/ECCM			Wideband Barrage Swept Barrage Spot	11	6 x 6 x12 in.	14	G	5, 6, 7, 9, 11	Brassboard Tested with Exdrone
Radar Jammer Fairchild Weston	Noise Jammer against radar	200	Set on Voltage Tuned Magnetron (VTM) 1 - 10 ghz	Swept Barrage Ajustable BW: 50 - 500 Mhz & Spot Noise	19	10.2 x 8.9 x 5.4 in.	532	G	5, 6, 7, 9, 11	NDI
Radar Jammer Hercules	Noise Jammer against Radar	100	VTM 0.8 - 15.5 ghz	Barrage & Spot Noise	9 - 12	8 x 6.5 x 5		G	5, 6, 7, 9, 11	NDI
Comm Jammer Fairchild Weston	Barrage Jammer against both voice & data comm Repeater Jammer against both conventional and freq agile radios	20 - 50	20 - 500 Mhz	Barrage noise against voice and data signal. Repeater against FM voice communications	14	9 x 9.5 x 7	198	G	5, 6, 7, 9, 11	NDI
SPEW Motorola	Early Warning, GCI & HF Jammer		C/D/E Band		56	0.75	510	G*	6, 7, 8, 9, 10, 11, 13	Prototype
ACE Motorola	Tactical Communications Jammer (16 Simul. Chan)	100 (2 x 50w)	20 - 100 Mhz (920μSec) (Band Search)	1 - 16 Noise Spots 80 KHz BW	35	0.28	500	G*	6, 7, 8, 9, 10, 11, 13	Prototype

*Ground tested, flyable hardware ready for flight test

COMMUNICATIONS RELAY PAYLOADS

Communications relay payloads extend the transmission range of data and/or voice communications systems. Tactical ground radios have effective ranges from 3 to 35 km, depending on terrain. Combat forces may conduct operations while separated by 50 to 60 km - well beyond the ranges of their communications equipment. Tactical airborne relays provide the link for extended communications.

COMMUNICATION RELAY

Name & Manufacturer	Mode of Operation	Freq Coverage (Mhz)	No. of Channels	Compatibility	Weight (lbs)	Size (cu. ft)	Power (w)	UAV Compatibility Factor	Anticipated Missions	Maturity
ARQ - 49 Naval Avionics Center (NAC)	Half Duplex Fixed Channels	Xmit: 256 - 264 270 - 278 284 - 292 Receive: 330 - 366	3 2 Voice & 1 Data	ARC-182 & Link 11	720 w/Pod		2000	R_1	1	Production Deployed on A-6
Shipboard SINCGARS (NAC)	Simplex Freq Hopping	Xmit & Receive 30 - 88	2 Voice & Data	SINCGARS	200 w/ Pod	7.02	858 2	R_2	1,3,5,7-10,12,13	Brassboard to be Deployed on UH-1
Pioneer Relay AAI	Simplex w/ Scanning Receiver Set on 5 Channels	Xmit & Receive 30 - 400	1 Voice	ARC-182	40			G	1,3,5,7-10,12,13	Prototype on Pioneer
UAV Relay (NAC)	Simplex Fixed Channel Five Selectable Channels	Xmit & Receive 238 - 288 340 - 390	1 Voice	ARC-182	45	1.5	196	G	1, 3, 5, 7, -10, 12,13	on MAVUS
Common & Interoperable Comm Relay (NAC)	Simplex Freq Hopping	Xmit & Receive 30 - 88 225 - 400	2 Voice & Data	ARC-182/210 SINCGARS Have Quick 1,11	no more than 100		less than 1 kw	G*	1,3,5,7,-10,12,13	In Development

* This program is being pursued under the sponsorship of the JPO

APPENDIX E:
ACTIVITIES/LABORATORIES

Flight Control Division Wright Laboratory, Dayton, OH	--	UAV avionics development
Ft. Huachuca, AZ	--	Joint training center for UAVs
Integrated Missile Maintenance Center Redstone Arsenal, AL	--	JL- COE
Joint Development Facility Tysons Corner, VA	--	JII simulation and verification
Joint Technology Center and Systems Integration Laborarory Redstone Arsenal, AL	--	UAV joint test bed and bureau of standards for family of UAVs
Naval Air Warfare Center Aircraft Division Indianapolis, IN	--	UAV communications relay payload development
Naval Air Warfare Center Aircraft Division Trenton, NJ	--	UAV engine testing
Naval Air Warfare Center Aircraft Division Patuxent, MD	--	EXDRONE & MAVUS testing; MR engineering support
Naval Ocean Systems Center San Diego, CA	--	UAV computer simulation
Naval Air Warfare Center Weapons Division Pt. Mugu, CA	--	Lead activity for UAV DT&E and UAV OT&E support as requested
Survivability Information and Analysis Center Dayton, OH	--	UAV systems survivability
Yuma Proving Grounds Yuma, AZ	--	UAV demonstration flight testing
Harry Diamond Laboratory Adelphi, MD	--	MTI radar payload development
Lincoln Laboratory MIT, Boston, MA	--	MTI radar payload development

APPENDIX F:
POINTS OF CONTACT

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